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GEORGE BERNHARDT HARTMAN

in Recognition

of his

Service

in the

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at

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FOREWORD

A. L. McComb

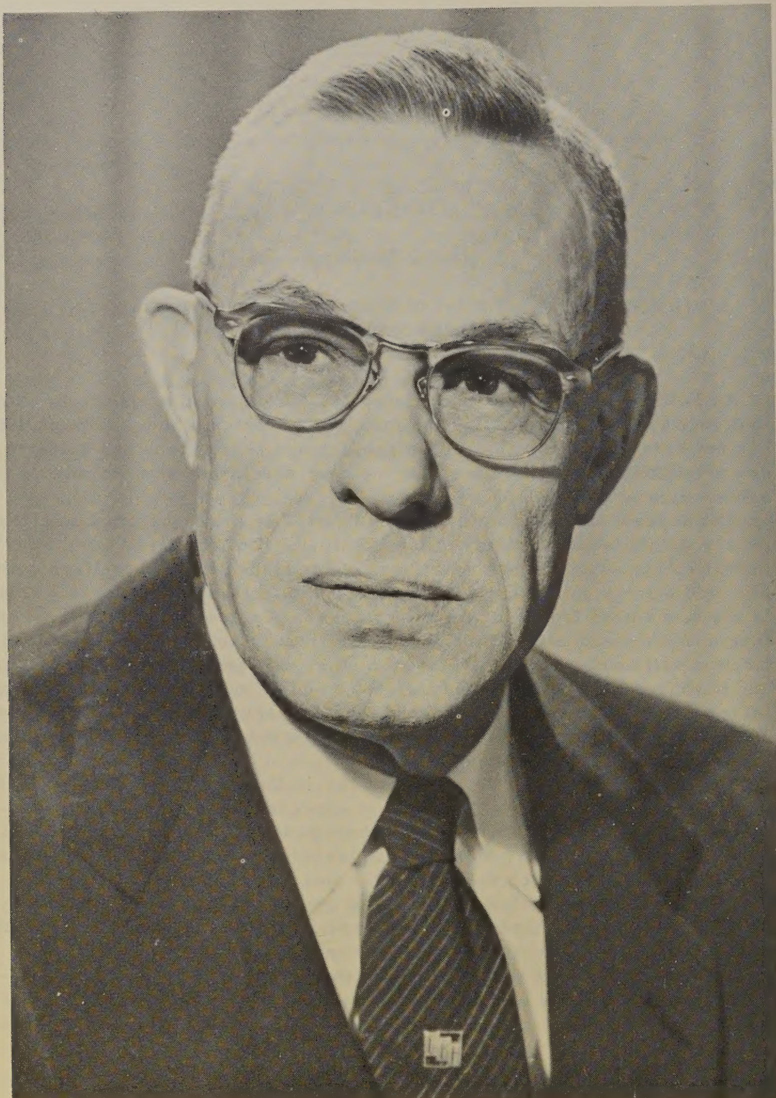
Head, Department of Watershed Management,
University of Arizona

As Professor Hartman relinquishes his administrative duties he can look forward to accomplishing the many things which a busy, fruitful life has not heretofore permitted. We, his friends, colleagues and students, are permitted to look backward a moment and honor him for his past achievements.

I first knew "Prof." Hartman when in 1935 he arrived from Louisiana to take up his teaching duties at Iowa State. From the first day "Prof" identified his own interests with those of his students, their welfare with his, and quickly gained their confidence, admiration and respect. This is the sound base from which a good teacher operates and Hartman never forgot that the aim of teaching is to build men of high ideals, equipped intellectually and emotionally to solve the problems to be faced within and beyond the University. He insisted on high moral standards with a tolerance, good humor and humility that are always refreshing. Class after class of students look back on his personal help and persuasive counseling with the fondest memories.

The basic honesty and concern for the welfare of other people, that made it possible for "Prof" to work so successfully with students, carried over into public relations and administration. He enjoyed the full confidence of his forestry staff and his leadership resulted in harmonious working conditions which permitted the steady advancement of the program of instruction and research in a growing department. Forestry programs within Iowa and forestry education within the nation benefited from his genuine interest and wise counsel.

We who have known Professor Hartman know that relinquishing administrative duties will not mean the end of his influence. He is not built that way. Of his past work nothing more need be said than that his achievements resulted from aiming high and being steadfast of purpose.



Professor George Bernhardt Hartman

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PROFESSOR GEORGE BERNHARDT HARTMAN

G.B. MacDonald and George W. Thomson

Department of Forestry
Iowa State University of
Science and Technology, Ames

George Bernhardt Hartman was born November 28, 1894 in Valley Junction, Iowa, where his father was employed as an engineer for the Rock Island Railroad. In 1903 the family moved to Eddyville where George grew up to have an everlasting interest in railroading and where he learned to love rural Iowa with its woodlands and streams. It was this interest in the out-of-doors that caused this young man to select forestry as his field of study when he entered Iowa State College in 1913.

His potential in forestry and allied fields was early discovered, especially by the personnel of the forestry and botany departments. This may have been a factor in his increasing interest in forestry. By attending Iowa State's first forestry camp in 1914 at Cass Lake, Minnesota, he was able to see at first hand the devastation of the great northern forests by improper logging, as well as to get an insight into both state and national forestry activities. In order to broaden his experience he spent a summer as a student assistant on the Plumas National Forest in California. For a six months period after graduation he traveled the areas from Minnesota to Pennsylvania as a part of the first concentrated effort to analyze and control the effects of the white pine blister rust.

During World War I, Hartman served in France in the Twentieth Engineers in the forestry battalion commanded by one of this country's outstanding foresters, Colonel William B. Greeley. After hostilities ended Hartman taught dendrology at the A.E.F. University located at Beaune in eastern France. Here he was first exposed to the experience of teaching and also to a first-hand contact with the classic French and German ideas of land management through forestry.

From 1919 until 1935 Mr. Hartman was associated with the Long-Bell Lumber Company (Wood Preserving Division) at DeRidder, Louisiana, in various capacities, the last of which was plant superintendent. He was again employed by the Company from 1947 to 1948 as assistant general manager of the Hudson River Division at DeRidder, Louisiana. During this latter period he was a member of the first official board of the Louisiana Forestry Association and is now a charter member of the Association. During his years in the South Hartman was to see the vital part that forestry could play in the rehabilitation of worn-out land, and there is no doubt that the cumulative effect of these early experiences was to make him a champion of forestry and sincere advocate of wise land use.

In 1920 George Hartman married Mary Gertrude Moore of Many, Louisiana. They have three children, Jean, George Jr., and James.

Jean married an Iowa State forester, Ladd Belehrad, and now lives in Louisiana. George Jr. followed his father's footsteps as a forestry graduate. He is married and is now employed on the staff of the Bureau of Land Management in Portland, Oregon. James followed the medical profession, is married, and now is an orthopedic surgeon at Ann Arbor, Michigan.

In 1935 Mr. Hartman joined the forestry staff at Iowa State College and served successively as assistant professor, associate professor and professor of that department, becoming department head in 1948. During this period he completed work for the degree Master of Science. This involved a research program resulting in the preparation of a thesis on the "Early History of Lumbering in Iowa," which is a valuable contribution to Iowa history.

Through all of Professor Hartman's service to Iowa State University he has been counselor to forestry students and thus eighty per cent of the 1,231 forestry graduates of Iowa State have been wisely counselled by this man. If the statement is true that, "A teacher affects eternity: he can never tell where his influence stops," then Professor Hartman has made an indelible impression on American forestry.

Since 1939 he has been a member, and is now a Fellow, of the Society of American Foresters, serving the Society's Division of Education as secretary in 1950, as vice-chairman in 1951 and as chairman in 1952 and 1953. Since 1948 he has been a member of the Council of School Executives of the Society.

In July, 1953 Professor Hartman was first appointed by the Governor of Iowa as a member of the Iowa Natural Resources Council. This appointment has been extended by two successive governors and his current appointment is to continue until 1965. Concurrently with his extensive teaching, administrative and counselling duties, he has been active in the American Wood Preservers Association; for several years he was chairman of the Association's Commodities Committee.

Professor Hartman has maintained a broad interest in University life of both faculty and students. Because of this interest he was elected to the Athletic Council of the University representing the College of Agriculture. He served several years in this capacity. He is a member of the Sigma Pi social fraternity, the Gamma Sigma Delta, Phi Kappa Phi, and Alpha Zeta honorary fraternities, the Iowa Hoo-Hoo Club No. 102 of Des Moines, Iowa, and the Ames Kiwanis Club.

Professor Hartman's philosophy has always been that a student, however brilliant as a technician, will fail in his contribution to society if he does not have implanted in him moral and ethical values, so essential in our age. He has spent long hours and much effort in conserving these values, not only in his Department, but also as a citizen in his community. All through the years he has been active in his local church as teacher, trustee, finance officer and adviser. He has served the Iowa and American Baptist conventions on several committees and commissions.

Through his more than forty years of professional life, Professor Hartman has maintained a high and knowledgeable interest in forestry and conservation. His contributions to the profession are acknowledged by all who have come in contact with him.

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TEACHING FORESTRY ECONOMICS

William A. Duerr and Frederick S. Hopkins, Jr.

Chairman, Department of Forestry Economics, State University College of Forestry at Syracuse University, and Assistant Professor of Forestry, Iowa State University of Science and Techology

Surely, at the root of it, the problem of teaching forestry economics is not a bit different from that of teaching any other subject: It is a problem of the instructor's understanding and of his communication with the students. And yet for every subject the form of understanding and communication is partly different. And for forestry economics, growing and changing as it is today, the differences—and, too, the similarities—are important to forestry and to the academic community.

In this article, written in tribute to a long-experienced teacher by two comparative newcomers to the blackboard end of the classroom, we should like, with humility, to state our ideas about understanding and communication with reference to teaching the economics of forestry to undergraduates.

Introductory Economics

Foresters, in our experience, commonly look back upon their introduction to economics with dim but still unjoyous memory. Even professional economists, we find, often aver that they chose their field despite its introductory course. Not long ago, a committee of economists studied undergraduate instruction in economics. This committee offered as one finding, not altogether in jest, that to teach successfully the introduction to economics is impossible!' What's wrong? So far as the foresters are concerned, there are perhaps two major difficulties.

First, it is hard for the student, and evidently for the teacher too, to relate the course to the curriculum. After working his way with reasonable purpose through a term or so of general forestry, botany, mathematics, and the like, the student arrives, customarily in his sophomore year, at the threshold of economics. This subject, he has been led to believe, will be good for him—but, like any good medicine, hard to swallow. To his somewhat open mind is introduced such assorted matters as the structure of the steel industry, marginal cost curves, and the fact that a second hamburger will not add as much to his pleasure as the first one did. As liberal education it is apt to be a dull experience tinged with unreality. As forestry it is at best tenuously related. Its relatedness is not strengthened by the gap of perhaps two or more college terms that may then intervene before the student takes up his economics on the applied level.

Second, it is hard for the student to adjust his mind to the point of view and method of social science. Oriented and motivated to trees and to biology and engineering, he is suddenly asked to think in terms of human

beings and their goals. For a fellow human being this should be no great shock but somehow it is: either a shock or a failure to grasp the point. In a realm where instinctively he uses inductive thinking and the case method, he is asked to think deductively and apply abstract models. And in the midst of a curriculum largely devoted to stating predetermined facts and procedures, he is all at once plunged into a pool of uncertainties, with endless alternatives to be weighed. Typically he shuts his eyes, swims hard, and escapes back to safe ground as quickly, and with as few after-effects, as possible.

It is not our purpose here to analyze the introductory economics course. But our comments concerning it do serve as a theme for discussing forestry economics: the sort of understanding and communication that may well go into the teaching of it.

Understanding the Purpose

Certainly one essential element of understanding on the teacher's part is to see his aims clearly. We believe that the purpose of teaching forestry economics to undergraduates is three-fold.

First is the purpose of establishing man (not the tree) as the central figure in forestry. The purpose is to depict human goals—those of society and of individuals—as controlling forest land management and forest industry. To this end, the teacher stresses the consumer, making clear that consumers provide the only reason for existence of the forestry profession, and emphasizing that the public interest is in the last analysis the interest of consumers. The teacher stresses, too, the landowner's goals. Forestry students tend during their four years to acquire rather firm concepts of forestry practice that is "ideal" by physical standards. If they do, then after graduation they are repeatedly frustrated to find that what the landowner is willing to undertake falls far short of this ideal. They are compelled to compromise, and may end by feeling cheated of the opportunity to practice the highest form of their profession. However, their studies in the economics of forestry should help them to escape naive frustration by appreciating that the best forest management in one situation may be quite different from what is best in another, even though the physical factors are identical.

Second is the purpose of giving the student certain specific tools and procedures and some knowledge of how to use them for guiding decisions or for comprehending events. Boiled down to fundamentals, the list of these devices is not very long. It includes marginal and budget analysis, related guides to choosing among alternatives, the concepts of supply and demand, indifference analysis, methods for prediction and planning, and certain procedures of peculiar significance in woods forestry, notably those for working with capital, interest, and time. If the subject of forestry finance or other business aspects of forest management has been shifted into the forestry economics sequence of courses, as is being done at some of the forestry schools, then the list of devices becomes longer—though, in terms of fundamentals, only slightly longer.

Third is the purpose of helping to integrate the curriculum. The aim of synthesis is common to many upperclass courses, and properly so where the aim can be pursued without sacrifice of subject matter. Each teacher's effort to synthesize gives the student a fresh slant on the cen-

tral goals of forestry. The study of forestry economics contributes to integration through its emphasis on human relations, its construction around the subject of planning by the firm and by society, and its attention to the whole context—the whole business, the whole economy—in which human planning is done.

Understanding the Subject Matter

One takes it for granted that the teacher must understand his subject matter. But still the point bears emphasis. The ideal instructor of forestry economics would be not only a dedicated teacher, but also a dedicated forester with an appreciation for the woods and its silvicultural and multiple-use problems. He is a zealous student of the conversion industry with at least a general working acquaintance with its technology. He is a devoted specialist with a strong flair for thinking as a generalist.

In forestry-economics circles, there is a still prominent school of thought which has held that the complete forestry economist is first an economist, second a forester, and third an amalgam. We see this person differently. Without for a moment disputing the necessity for a good deal of general economic theory in his educational background, we view him first as a forester, second as a forestry economist.

Furthermore—and still speaking wistfully—the complete forestry economist cannot be made in the classroom. To be sure, academic education is necessary, with preferably a gap between undergraduate and postgraduate work, a time for maturing, for experiencing, and for gaining tolerance for the social-science viewpoint. But learning theory is easy; the hard job is applying it. After finishing postgraduate work, the forestry economist has still to be completed by knocking about as a practitioner. If he must remain attached to the academic world, then ample research responsibilities will be of some help to him, and consulting work besides will improve him vastly. What he will be striving for is sufficient maturity to convey his technical principles to students in terms harmonious with ordinary life.

The great teacher, the ideal of all of us at the blackboard, teaches out of great depth. So ample is his stock, and so fast is it being replenished and enlarged, that he can give abundantly to his students with always an abundance to spare.

Communication

Even the great teacher may need some special means of communication beyond his own word and gesture and his own gift for inspiring scholarship. He may find use for special aids in arousing his students and setting them to work. For the majority of forestry economics teachers, such means and aids may be indispensable.

It has been customary over the years for college people to regard mathematics, physics, and chemistry, botany and surveying, forest measurement, and indeed the majority of both basic and applied courses as requiring not merely thought but practice for satisfactory learning. Ordinarily this has meant supplementing lectures and recitations with laboratory sessions for the students. And yet in economics and forestry economics, mere reading, talk, and quiet thought often have been viewed as sufficient for the process of learning.

The human mind, marvelous though it is, is yet for most of us a poor thing that needs sensual props in order to function at all well. The exceptional student may be able to solve a mathematical problem while staring at a blank wall, but most of us have to work it out on paper by pushing a pencil. We may need to use a concrete example, or even a physical model, to test and understand what we have done. The exceptional student perhaps can fully grasp the scaling of logs by reading and thinking about it, but most of us have to try it out and get the feel, the sight, and the sound of it. By the same token the rare mind can by its own force penetrate the subject of forestry economics. But most students can understand the subject best when it is presented in fairly concrete terms.

Forestry economics has been taught as a laboratory course in at least one of the forestry schools for a number of years. The laboratory approach has proven to be suitable and successful, and interest in it has spread.

We believe that the laboratory is a powerful aid in the teaching and learning of forestry economics and that in time it will be widely adopted for this purpose in the schools of forestry. True, one thinks of social science, and correctly so, as a field to which the experimental method has little application. Yet at the classroom level in applied economics one can devise many instructive experiments—for example, in consumer preference and demand, in marketing, and in production functions and organization. What better way to learn the principle of diminishing returns than to discover it oneself! And what better text for lectures than data the students themselves have created!

Aside from experiments, all parts of the field of forestry economics abound in practical problems well adapted to laboratory study and solution. In this area the forestry economics laboratory resembles the forestry mensuration laboratory. The tools and materials—such as the slide rule, graph sheet, and raw field data—are similar. And the objective is the same: Learning by doing.

The use of the laboratory not only helps effective transmission by the instructor but also improves reception on the part of the student. It is the responsibility of the instructor, and often his greatest challenge, to so stimulate the student that he becomes eager to understand economic relationships in forestry. The laboratory presents the opportunity to project the student into his role as a practicing professional forester. As the student comes to visualize more clearly some of the economic aspects of problems he can expect to encounter during his career, his motivation for understanding the economics of forestry is strengthened. The results, we are convinced, is a more competent forester.

Partly related to the laboratory is another of the devices that promise to spread into forestry economics and clarify its teacher-student communication: the case study. This device is useful in the problem laboratory and in lecture and discussion. It is highly appropriate to the integrating function of forestry economics.

The case study is generally looked down upon in economics circles as a business-school method, inductive and institionalistic. Indiscreetly used, it can present grave risks of superficiality and cook-bookery. But case studies hinged to a clear discipline, and carefully chosen to

illustrate the tightly reasoned principles of the course, can free these principles from the bonds of abstraction, enliven them, and make them understandable. The use of cases can also serve to put forestry economics in the context where it belongs: of studying ordinary problems and their solution.

Trends in Forestry Economics

The ordinary character of forestry economics has manifested itself slowly and a bit painfully. In the United States in the 1930's, the grave and complex economic problems of depression time began to attract a few foresters into postgraduate study of economics. These men at length emerged from the ordeal with a passable knowledge of academic theory and the stupendous challenge of applying it to forestry. Their success with this integration was at first meager. Among their economics classmates they gained a reputation only as foresters. Among their own profession they became marked as economists, capable of discussing any issue unintelligible. They were happiest in the rare company of their own ilk. When the handful of them met in the early annual meetings of their S. A. F. Division, their principal topic was, "Who are we? What is our mission in life?"

Their identity and mission became clearer as by stages they welded their forestry and economics. For instance, just after World War II their Forest Economics Division sponsored a project from which came a book on "Research in the Economics of Forestry". This book defined the scope of the field and illustrated its research content by outlining some 120 studies that could contribute to developing the essential body of knowledge.

It is interesting to note that most of the 70-odd writers who contributed to the research book were general foresters, general economists, and agricultural economists, who were in position to give only passing attention to forestry economics. One chapter of the book reported on a survey of research in the United States. It revealed that only 33 persons had concentrated in the field during the decade of the 1940's. Of these, 13 held the doctor's degree (in economics or other subjects), and only 4 were on forestry school faculties.

Since that time the numbers of persons dedicating their interest to the economics of forestry has grown a good deal. A directory of workers in the field, published in 1959, listed more than 300 names. The colleges have been turning out more foresters with graduate schooling not simply in economics, but in forestry economics in the ever truer sense of an integrated discipling. Many of these men have gone into government service and into private industry. But some of them have joined the forestry school faculties to work upon the fascinating problems of teaching forestry economics. In support of their efforts, two textbooks have appeared, in 1959 and 1960.

Meanwhile the growth of the group and its better orientation to forestry have been evident in the annual meetings of the S. A. F. Economics Division. No longer gatherings of a little clan for introverted reflection, these meetings have attracted good crowds, come to hear and talk about the everyday, vital economic aspects of their work.

What accounts for the growth of this field of forestry economics over

the past two decades? Surely, it is not simply that a small number of foresters so inclined have managed to inflate their own empire. Rather, it is largely a matter of growing values of both the resources employed in the production of forest goods and services and the benefits derived. The losses that follow errors in planning tend to be more substantial; more is to be gained by exactness in decision-making. If the full contribution of forestry to the private firm or to society is to be achieved, there is increasing need for the methods of economic analysis, and for refinement of the basis upon which decisions are made.

The continued vitality and growth of forestry economics will depend upon the success of the specialists in directing their effort more and more closely to the plain and pressing problems of resource management and use. And as the field is brought thus nearer to the ordinary business of life, we can expect those of the specialists who are teachers to be doing an increasingly effective job of putting forestry economics across to undergraduates.

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FORESTRY EDUCATION — PYRAMID OR TREE?[1]

A.E. Patterson

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Since the end of World War II, and until the period of the Sputnik, forestry educators had been besieged by other educators and persons in industry to overhaul the standardized forestry curriculum in favor of a more "liberal" or "general" education curriculum. Since Sputnik, this pressure has decreased to some extent, and in some instances the pendulum has swung to the opposite extreme. Perhaps this present period of uncertainty is the time to carefully examine these pressures and the reasons behind them. To examine them in chronological order would seem to be the most logical approach.

Over a period of nearly fifty years, forestry education in the United States developed along approximately the same lines in nearly all of the universities in which it was a part, and without regard to the section of the country in which it existed. In most cases, beginning with a few courses it gradually expanded until approximately one-half or more of the course work could be called forestry, or was at least in fields associated with forestry. The extent of this trend was more defined in some schools than in others. The question arises: Why did this expansion of course work occur?

There are many answers, depending upon the individual university, its faculties, and its philosophies. In some instances there is no doubt that curricula in new schools, or changing curricula in older schools, were copies of curricula in older or more successful schools. In other cases they were copies of a curriculum to which a strong-willed professor had been subjected, and were continued under the theory that "what was good for me is good for my students." Again, they were the result of attempts by faculties to teach more courses, so as to build up teaching loads and thereby more fully to justify themselves in the eyes of the university administration. Many times, however, they were the result of demands by employing agencies for graduates with specialized skills. An example in point refers back to the early days of the Civilian Conservation Corps, when the remark was made that more foresters were found unsuitable for CCC work because of their lack of knowledge of surveying techniques than for their lack of knowledge of forestry. Shortly thereafter, many forestry schools instituted more rigorous courses in surveying, many of which still exist after more than twenty years. Apparently, no one thought to ask why civil engineers were not hired to do the surveying work! Another example might be the expansion of the forestry curriculum into the field of pulp and paper technology.

[1] With apologies to Dr. Joel H. Hildebrand, professor emeritus of Chemistry, University of California.

Surely few will disagree with the statement that such a field lies close to the heart of the chemical engineer. Example after example of this type could be cited, but it is not necessary to do so to make the point that many curricula in forestry were the result of demands by the employers. In effect, the forestry schools had a product to sell. If the product pleased the purchaser he would buy it; if it displeased him he would make his purchases elsewhere, and the bypassed school would begin to wither on the university vine.

After World War II, populations were sick of violence and begging for an idealistic world of peace and plenty. Science was often pictured as an ogre; and education, the backbone of science, was held up for the closest scrutiny. Many persons were convinced that the kind of education which had brought the United States to the peak of wealth and plenty, was at fault. Here was an opportunity not often presented. Now was the time to burst the chains of stark realism, and to delve into the placid waters. Foresters, engineers, scientists of all kinds were closely examined in the glare of "liberal" or "general" education, and by the standards of the proponents of "liberal" or "general" education they were found wanting. Few foresters, engineers, and other scientists were versed in the fine arts, the languages, or the social sciences. They had spent their college careers, unfortunately, in learning to make a living, rather than in learning to live a life. No quarrel can be picked with the proponents of the "liberal" or "general" education regarding their findings. Based upon their criteria and their standards, they were correct. Questions do arise, though, as to the standards proposed, as to the means of application, and as to the reasons behind this drive for greater acceptance of the broader education. For instance, if the real purpose of the "general" or "liberal" education is to teach the student to learn to live a life, whose particular idea of life is he learning to live? His? Or someone's idea who devised the curriculum? Is it plausible to suggest that not all enjoy the same things, and that one person's inability to fathom the intricacies of a symphony concert, the writings of the great authors, or the paintings of the masters, makes him any less happy? Perhaps he would rather go fishing in his leisure time!

Of course there is the argument that the student can better understand his fellowman and will thereby be more tolerant if he is more widely educated. There is no doubt that this is true, but can we ask if this tolerance can be acquired in a few short years in college, or is intolerance the result of years of conditioning previous to college which will take as many and perhaps more years of conscious, wilful study and desire to erase it from his mind? And will the forceful act of requiring the student to study the "general" courses make him more tolerant, or will the very nature of the forceful act make him more resistant to understanding, and less tolerant? Perhaps we do not have answers to these questions; more likely each person must answer for himself, and judge his own reactions.

For several years we have been listening to representatives of industry plead for forestry graduates with a more "liberal" education. This more "liberal" training, they say, is necessary because much of a forester's work is dealing with people, and unless he can deal properly

with them he will never be able to get his forestry program into operation. Also, they state, they wish to look upon their foresters as executive material, and that those persons with a "liberal" education make the best executives.

Perhaps these statements are true, and certainly most persons can cite specific examples to prove the point; but let us examine them a little more closely. First, it is quite evident to anyone who has dealt with the persons from industry who interview students for employment that this same line of reasoning has apparently not filtered down from the upper echelons of industry (where such statements usually originate). Seldom do the interviewers ask for the student's grades in literature, social science, or the fine arts, or even inquire if he has had such course work, but they are quite specific in their questions about the student's abilities in such things as dendrology, mensuration, silviculture, management, and other forestry subjects. These persons, of course, are not interested in whether the newly hired forester will make a top-flight executive fifteen or twenty years from now. They are interested in whether he can do the forestry job assigned to him the day he reports for work. Since these persons who hire young foresters, and those who supervise them, are going to be the ones to pass judgment on them, and since that judgment is going to be based upon whether or not the young forester can do the immediate forestry job, and since the ability to do that immediate forestry job is going to reflect upon the interviewer's ability to judge men or handle his personnel, it is quite evident why the interviewer and supervisor are concerned more with the young forester's ability to do forestry work than with his knowledge of "how to live a life."

As for the future executive prospects of the young forester, surely some will rise to the top. They have in the past and have accounted for themselves in a good manner. Will the "general" or "liberal" education bring forth more of these executive types? A statesman who was asked by a young politician whether he should concentrate on politics or statesmanship, answered: "Son, concentrate on politics, for if you are not a good politician first, you will never have the opportunity to be a statesman." This could be very well rephrased to apply to the young forester. If he is not a good forester first, he will not be with the company or agency long enough to find out if he has executive ability.

Surely one thing is true, only a certain amount of material can be included in a four-year college curriculum. Add more courses, and something must be eliminated. Should several "liberal" education courses be added? If so, what should be excluded? Should it be silviculture, or mensuration, or dendrology, or fire protection, or finance and economics, or forest management, or utilization, or ..... ? Something has to go!

If it is agreed that something must go, there is one standard answer: Industry and state and federal agencies must undertake a larger program of in-service training which will fill in the gaps in professional training created by the forcing out of professional courses by the inclusion of nonprofessional "liberal" education courses. It sounds like an ideal solution; but even if industry and the forestry agencies agree, are they capable? In-service training of this sort is not the in-service training with which most of us are familiar. It is not the short-course type of training, nor the show-me trip, nor the on-the-job mechanical know-

how, nor woods-type training. This in-service training must be bedrock fundamentals, concentrated study, prepared lectures, library reading, and the outside problem-solving type of training. This is professional training and nothing else. This is collegiate training not obtained in college, but of the same caliber. Nothing short of this will be satisfactory; anything short of this will lower professional standards. Are industry and the agencies ready to assume this responsibility? Do they have the personnel available in each field of forestry, capable of conducting such course work? If they are capable, do they have the time available? Most professors find teaching to be a full-time job.

Of course there is always the possibility of extending the four-year professional forestry curriculum to five or more years. This is not a new nor an untried idea. Several professional forestry schools have tried it and dropped it. Various reasons have been given why it was unsuccessful. Principal among these was the fact that it still led to the Bachelor's degree. An additional year of work and expense for the student with admittedly more training, but nothing different to offer the prospective employer in the way of a degree than could be offered by a four-year graduate, was not conducive to popularity. It didn't take the students long to beat a path to the school where they could get the degree in four years. But why not give the five-year man a different degree or an additional degree to show his additional worth and effort? It is already being done; it is called the Master's degree.

Of course, if all professional schools of forestry were to adopt the five-year plan leading to the Bachelor's degree, would not the problem be solved? Why hasn't it been done? This is no new idea; it has been proposed for twenty or thirty years. Even the Forestry Compact schools of the Southern Regional Education Board (which are more closely allied than those in any other region) have not been able to agree on this proposal within the Southern region, much less the country as a whole. Why hasn't it been done? There must be a very good reason. In addition, in case of such a possibility becoming a reality, industry and state and federal agencies must be prepared to foot the bill by paying higher starting salaries, and backing up forestry school administrators' demands for increased budgets for larger faculties and increased instructional costs.

But what of the other side of the coin? Surely there is some basis for the employers' demand for this broader education. What kind of young forester do they actually want? One of the largest employers of foresters in the southeast has listed the following criteria as being the traits or accomplishments they desire in their forester employees:[1]

1. He must be intelligent, have technical forestry know-how, and be able to use it.
2. He should know the fundamentals of forestry, and know the "why of forestry as well as the "how."

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[1] What Industry Expects from a Young Forester. Earl D. Redman. Forest Farmer; vol. XVII; No.12; August, 1958.

3. He should have the ability to express himself orally and in writing, be able to communicate his ideas to others, and should have a good vocabulary.
4. He should be cooperative, patient, and have the ability to work with others, the desire to compete, and the will to work hard.
5. He should be ambitious and have leadership ability, but should also be a good follower.
6. He should be well-balanced between scholarship and sociability, and should have an interest in things and events outside of his job.
7. He should have curiosity and should not have to be prodded into thinking.
8. He should be a mature person, not in age alone necessarily, but in sincerity, integrity, humility, courtesy, wisdom, and charity.

These are the criteria from one industry; they may not satisfy all industrial employers or all forestry agency employers, but there can be very little criticism of them as a goal toward which young foresters may strive. Certainly, however, there have been few such paragons of manhood in the past who could qualify under all of these criteria, and there will likely be few in the future; but goals should always be beyond reach, and lack of fulfillment in no way detracts from their value.

Examining the above listed criteria, it seems as though the first two are probably being well handled by the forestry schools today. In most instances industry and the forestry agencies have little criticism of the technical training of young foresters. They are not so generous in their praise of the same foresters with reference to criterion three. And although no refuge can be found in the fact, the same criticism can be heard of young engineers, pharmacists, geologists, doctors, chemists, and practically every other group of young graduates including the lawyers, who make a fetish of interpretation of the written and spoken word. Apparently the communication of ideas and the use of the mother tongue in oral and written expression is being sadly neglected.

University faculties have only two excuses for this situation. First, speaking and writing habits are seldom the result of formal instruction, but rather the result of mimicry of others, particularly in the home and community. Secondly, no matter how many courses in grammar or speech to which a student is subjected, he cannot be taught if he does not wish to learn, and he will not change unless it is his own desire to do so. This, of course, in no way allays the responsibility of the schools to continue to teach more grammar, and more composition until the student learns to communicate properly, in self-defense if for no other reason.

Thus, the first three criteria are undoubtedly a part of the present school of forestry curriculum, and could probably be improved. But what of the remaining five? Are these covered by any course or group of courses in any college curriculum? They may exist, or perhaps they can be developed; they may even be the result of a "general" or "liberal" education, but can these things be taught in so short a period as is given to a college education? Or are they the result of life's experiences, and maturing spiritual growth of the individual?

These two possibilities: (1) That a "liberal" education can be acquired

in college; or (2) That a "liberal" education is largely the result of life's experiences, are the fundamental bases for two distinct philosophies of education. Those who believe a "liberal" education to be of such a nature that it can be acquired in college, frequently demand that the first two years of college work be in the field of liberal arts, and that the student not be allowed to specialize or even show preference for a life work until he has completed his second year of college work. This approach is frequently termed the "pyramid" philosophy, since it supposedly develops a broad base upon which later specialization can rise to a peak.

The second philosophy is based on the belief that "liberal" education is largely the result of life's experiences, and is termed the "tree" philosophy. This "tree" philosophy is not new; in fact it has been practiced by scientific schools of all kinds ever since education emerged from the age of education only in law, medicine, and theology; and to a large extent even these have succumbed. Under the "tree" philosophy the broadening comes later, just as the tree branches more fully, blossoms, and bears fruit in maturity and not as a sapling. Caution should be aroused at this point, however; the "tree" philosophy does not envision a hide-bound curriculum which gives the student no choice of direction, but neither does it require him to spend two years of time, effort, and money, engaging in the pursuit of knowledge which will teach him to "live a life" in which he may not be the least bit interested, and may even resent.

There is little need at this point to discuss in detail the "pyramid" approach. It has been written about and discussed by so many persons in so many places that there are few who cannot recite at least some of its tenets. Suffice it to say that the proponents of the "pyramid" philosophy usually abhor the possibility of a freshman becoming excited about a career in chemistry, or botany, or animal husbandry, or forestry, or any of a hundred other possibilities. He must first be broadened before he is allowed to specialize. A good superstructure, it is said, requires a broad foundation. Perhaps it would be well for these persons to "specialize" themselves in a little "sidewalk engineering" at the nearest major building construction activity. They might be surprised to learn that the architectural engineers of this modern day do not build on a broad base; they build on a relatively narrow base, but one that is <u>sufficiently deep.</u> In fact it may surprise them to learn that they are not building pyramids any more; and that like the tree, the overhang of the building is frequently wider than its base!

It should be of value to terminate this discussion by a presentation of the more widely used, but less widely recognized "tree" philosophy as it applies to forestry education. Probably no better outline can be adapted than that followed by Dr. J.H. Hildebrand in his presentation of the subject at the 37th Annual Meeting of the American Council on Education.[1]

The "tree" philosophy is based on four propositions. First: <u>A forestry school should use its resources in furthering its most important functions.</u> That is, it should confine its teaching to professional fundamentals and not expend its time on vocational courses or practices

[1] Chicago, Illinois. October 14-15, 1954. Also published in the Phi Kappa Phi Journal; vol. XXXVII, No.1, Spring 1958.

which can be learned, or taught, on the job as a part of in-service training. Furthermore, it should confine itself to its own unique segment of the profession. No person, nor institution, can do all things equally well. It is fairly common knowledge in educational circles that the mediocre school will offer the most courses per professor; the better school fewer courses.

To further support the above proposition, the faculty should not be allowed to merely present by way of lecture only the materials already available in print. Such effort is a waste of both the student's and the professor's time. Lectures are one of the great methods of teaching; but often the lecture material is wrong. If the professor can bring only the book material to the classroom, the student will find the library a more convenient source of information, and the administration will find books less expensive than professors.

The professor's position should be that of a leader, a motivator, a spur to the student's thinking. The school of forestry should not be a place of compulsive study for the student, but a place of challenging opportunity. He needs to be guided, but not restricted; and if he needs to be constantly led he is either not of the caliber desired, or is immature. Unbridled election of courses has been criticized in many instances, and many times justly so. The system, however, is not at fault; the fault lies in the courses from which the student has the opportunity to choose. If only the better courses are offered, no problem will exist.

Proposition two states: <u>Students who evidence a serious intellectual interest in forestry should not have their fuller development interrupted by any preconceived arbitrary plan of "general" or "liberal" education.</u> Such students are a valuable property, and when they evidence interest educators are derelict in their duty if they do not give them every opportunity to develop to their greatest capacity. "Survey" courses usually do nothing but bore these students, if they do not altogether stifle them. If they are to attain their potentialities, their education must be fundamental and deep, not broad and shallow. They must be exposed to the <u>best</u> in their early formative years.

Proposition two, above, is not an argument against the broad education, but rather as stated in proposition three: <u>The time to interest forestry students in literature, fine arts, philosophy, and the social sciences is in the later years of his college education, or perhaps in his later life.</u> This is the true basis of the "tree" philosophy. To be effective the student must first become proficient in his chosen field, whether it be forestry, fine arts, or philosophy. Once he has a strong straight trunk of knowledge, deeply set and sturdy, he can send forth his branches into allied fields completely foreign to his specialization. Only then will he begin to blossom and bear fruit; and who can predict the fruit that may result from the cross-fertilization of the mature tree of forestry and the adjoining mature trees of the humanities?

Following the lead of proposition three, proposition four states: <u>Opportunity should be available for every student to study outside his major field of forestry.</u> He must have room within his curriculum to reach out, to explore, to relax his mind with those things outside his field which interest him and are of his choice. Extremist educators of

specialized curriculum will deplore this situation. They will say the young forester cannot learn all he needs to know in six or eight years and certainly not in four, if he does not spend all of his effort on his specialty. But how many of these same professors will admit to knowing all there is to know in their own specialized field? There is too much knowledge for any one person to have it all at his command, even in a specialized field. In addition, it must be recognized that knowledge is not a static thing; it is dynamic, and only the fundamentals are changeless. We must realize that the student who has mastered a reasonable amount of knowledge in his field, especially the fundamentals, can, if he has the will, master other necessary portions at a later date. It is also true that if he attempts to "survey" too many fields, he will be master of none. Or as the parody goes: "He will know less and less about more and more until he knows practically nothing about everything."

Scrutinize the propositions of the "tree" philosophy carefully and it will be seen that they do not call for a tightening up of forestry curricula, but rather a loosening, or liberalizing in a manner acceptable to the educator in the professional field.

The true "general" or "liberal" education cannot be wrapped up in two, or even four, years of college work. Intellectual maturity cannot be hurried. It will not be the result of a particular curriculum nicely balanced between departmental and professional claims. It cannot be set apart as a particular body of knowledge capped by a particular kind of degree. It is a lifetime process that can only begin in the college years among the specialists; but which will continue after graduation in the libraries, the churches, the professional societies, and the everyday contacts of man among men.

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SOME PIONEERS AND LEADERS IN AMERICAN FORESTRY AND CONSERVATION

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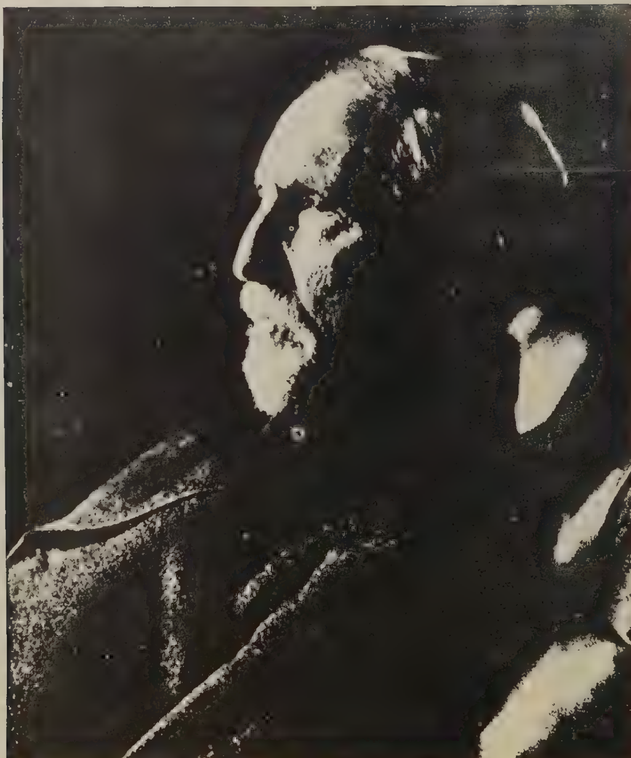
Previous to 1880 many American scholars and scientists expressed deep concern about the reckless exploitation, abuse and devastation of our forest areas, and the inevitable lumber shortage to follow. Several writers pointed accusing fingers at the destruction of the forests, the evils of soil erosion, the clogging of streams by detritus, impediments to river transportation, and the baneful effects on fish and wildlife generally. They regretted the failure of our Government to act and demanded legislation in Congress in the matters of conservation of our natural resources.

It will be impossible here to record all of these remonstrances. The purpose of this article is to recount the exceptional and telling efforts by a few recognized early leaders who made their voices heard and their ideas respected in a belt of states from Minnesota to Pennsylvania. It is well understood that energetic and ambitious men everywhere align themselves in distinct categories. Those who wish to amass wealth and fame; those who regardless of others, in politics or public office, render only lip service; and those who regardless of fame or fortune, give of their knowledge, character and influence for the betterment and happiness of mankind. It appears that those who we are here presenting unquestionably belong in the benevolent class. In this category we will also observe differences, in that some of our pioneers have effected distinct improvements during their brief span of life, while others have sown the seed which has been nurtured to bear fruit in generations to follow. Some have spurred the government to action; some have concentrated their fire on abuses and waste, while not a few have given of themselves unstinted to education and to the public understanding of the problems.

These pioneers and leaders maintained close and friendly contact with conservation-minded senators and representatives in state and national governments and thus facilitated favorable legislation. They were almost without exception men of humble origin, who had to struggle to obtain an education, and never ceased to acquire knowledge. They labored unceasingly and effectively in the cause of conservation and eventually rose to honor and eminence.

Almost every state in eastern U.S. is proud to honor champions of conservation; we could name several from Michigan, Wisconsin, Iowa and in the New England States, but space in this paper does not permit. The men selected for this article are Andrews and Green in Minnesota; Warder in Ohio; Lacey in Iowa; Rothrock of Pennsylvania; Filibert Roth in Michigan; Franklin Hough of New York; and Fernow in New York and Washington, D.C.



General Christopher C. Andrews
(Photo by courtesy of the Arthur H. Clark Co., Glendale, California)

General Christopher C. Andrews 1829-1922, and the Establishment of Forestry in Minnesota

General C.C. Andrews was born at Hillsboro, N.H., in 1829. The family lived on a farm at the Upper Village, a typical New England environment. The low hills and the valleys had largely been cleared for fields and pasture. Christopher was the youngest of four children. He was strong, active, and ambitious to learn and was deeply interested in books and in all the out-doors. At the age of thirteen years he entered his brother Charles' store in the very heart of Boston. After two years of this and by his brother's help he attended the Francestown Academy. Then began a life alternating with study, teaching and farm labor. After another period in the Boston store he entered the Harvard Law School, and afterwards became associated with a prominent law firm where he could also attend and observe court procedures.

Boston in the 1840's and 1850's seethed with discussions and discord

over the slavery question: Free Soil, Temperance oratory and the Gold Rush virus. Andrews here learned much of the great and timely questions.

Soon after the completion of his law training, marriage, and brief practice in Gloucester, he departed for Kansas (1850). This was jumping from the pan of discussion into the fire of action, for he arrived in Lawrence at a time when Missourians were forcing slavery upon Kansas and Nebraska, and the law cases he handled were concerned with settlers, Indians, cow hands and adventurers, —a rich and varied experience. This stay in Kansas was followed by travel through the southern states and a visit to Washington, D.C.; then he settled at Crow-Wing, Minnesota (1856) where he continued law practice and counseling for the Indians until the outbreak of the Civil War.

Andrews promptly volunteered and was enrolled as captain, and signed up twenty young men with whom he journeyed to Fort Snelling where his company was increased to 150. His first action was taking part in the capture of Little Rock, Arkansas. Later in the battle of Murfreesboro, where Major Lester surrendered against Captain Andrews' advice, he was made prisoner. Release came after eight months with exchange of prisoners. He soon re-enlisted, rose in rank and took part in the operations leading to the capture of Vicksburg. Finally, as Brigadier General with 12,000 men, his regiment captured Fort Blakely, Alabama. This happened in April 1865, on the very day that President Lincoln was shot.

General Andrews was kind to his men; instead of threats and rebukes he pursued a course of reasoning and advice; pointing out the undesirable consequences from lack of discipline or indifference. He was rewarded by friendliness and cooperation.

After a short period occupied with the process of reconstruction he was appointed U.S. Minister to Norway and Sweden. He traveled extensively on the Scandinavian peninsula and wrote more than 30 official reports on the life, industry and economy of those countries. Becoming much interested in the skillful management of their forests he determined to bring forest management and conservation to Minnesota.

It was after a period of two years as consul to Rio de Janeiro that he returned (1878) to St. Paul, where he formed a brief association in the publication of a newspaper which led to editorial writing. However, his deep and genuine interest in questions of public concern soon caused him to give assistance and impetus to waterways projects. He was a delegate to the International Reciprocity Convention; became chairman of the committee to erect soldiers' monuments at Vicksburg and other points in the South, and was active in the planning for the National Soldiers' Cemetary at Washington. The last twenty years of General Andrews' life were given entirely to forestry and conservation in Minnesota.

For many years the constitution of Minnesota practically compelled sale of the original 8.5 million acres of federally granted land. But at the turn of the century accumulation of burnt-out and tax-delinquent lands brought a change in the public sentiment. They amended their constitution, permitting the legislature to set apart public lands of the state better adapted for timber production than for agriculture. The legislature then promptly placed 350,000 acres of northeast Minnesota in state forests. In 1931 a large acreage of such lands was placed in trust of

public institutions, and more were later acquired from the relinquished tax-forfeited lands.

In the battle for the forests and all benefits directly and indirectly accruing from these, General Andrews gave of his experience, energy and wisdom. He firmly believed timber to be a fundamental element of colonial growth. He severely deprecated the unchecked exploitation and the government's lack of surveys and inadequate controls; the fraudulent claim entries, and the lack of fire protection. He sharply pointed out all the present and future evils of forest destruction. In lectures before schools, colleges and associations; in newspaper articles; in conversation with individuals and in conferences with legislators or their committees, he assiduously presented an overwhelming array of facts and figures to sustain his points.

In 1882 he attended the National Forest Congress in Cincinnati; where he read a paper on the necessity for a School of Forestry in the United States. He reviewed the whole question of forestry to show the vast incomes from the State Forests in different European countries; in the preparation of this message he drew upon his study in Scandinavia and also asked assistance from U. S. Ministers abroad. James Russell Lowell wrote from London that he would gladly help obtain information for his use, and help awaken the public opinion to conservation of the forests. Europe in 1880 had thirty schools for forestry while U.S. had none. General Andrews also pointed out that forestry began in the state of New York under Governor Grover Cleveland and that during his last term as president Cleveland acted upon the recommendation of those who urged wiser use of the forests and the establishment of forest reserves in U.S. Minnesota was a section of the country where thousands of new settlers were struggling to clear land, and where they were tempted to burn their brush (slash) in dry weather; where prospectors, hunters and tourists were likely to have camp fires; where busy logging camps and logging roads were present. Under these circumstances one can well imagine the liability of fires. It would require a great force of men to keep surveillance over twenty million acres. General Andrews therefore used every favorable opportunity to agitate the subject and he furnished several papers to the American Forestry Association. His paper "The Prevention of Forest Fires" for the meeting in Brooklyn 1894, was read only nine days before the terrible Hinckley fire in which 418 people died.

In 1895 to 1911 he discharged all the duties connected with forest fire prevention. The State Legislature was slow to channel appropriations for fire protection; usually much less than that requested. Consequently when 1910 with an extremely hazardous season arrived, the state and the organization were inadequate to the situation. In that year forest fires in Minnesota swept over 1,051,000 acres.

When in 1911 his labors bore fruit in the setting up of a more modern fire protection system under a trained executive, General Andrews was given the position as Secretary of the State Forestry Board and continued to fill this office until death in 1922. One important activity which this office performed was to collect data and accomplishments of other countries, which for several years became an important source of information on European forestry available in this country.

At long last General Andrews' efforts paid off; the people of Minnesota clamored for fire protection and laws for better use of the forests were enacted (see record of enactments by Weber). General Andrews is credited with 12 technical papers in the field of forestry (Munns).

Dr. Samuel Bowdlear Green, 1859-1910, Minnesota

Dr. Samuel Bowdlear Green was born at Chelsea, Mass., 1859. He graduated from Amherst College in 1879. There he continued graduate studies and became an instructor. He also traveled in Europe where he observed research and practices in agriculture. Later he gained experience in this field by assignment to the Agricultural Experiment Station at Cornwall-on-the-Hudson. Upon the completion of his studies in 1888 he was selected to man the newly established Minnesota Agricultural Experiment Station and not long afterward he was appointed Professor of Horticulture at the University of Minnesota (1892).

From the very beginning in Minnesota Dr. Green was an active leader and organizer in the fields of Horticulture and Forestry. By travel, speaking and writing he lent a very strong support to the advancement of forestry, constantly urging legislation and the promotion of forestry education. One of his colleagues, Professor Snyder, pays him a handsome tribute:

> "Dr. Green was very practical in his endeavors, and by tact and good will he obtained cooperation. He succeeded in winning and holding the support of the lumbermen. He was strong, wholesome, honest, fearless, unselfish, energetic and courageous, but amiable and genial always, his countenance radiating and his voice ringing with sincerity. He was capable of working hard for long hours. In reviewing his accomplishments one is filled with wonder that he was able to do so much." (Minn. State Hort. 39:416. 1911)

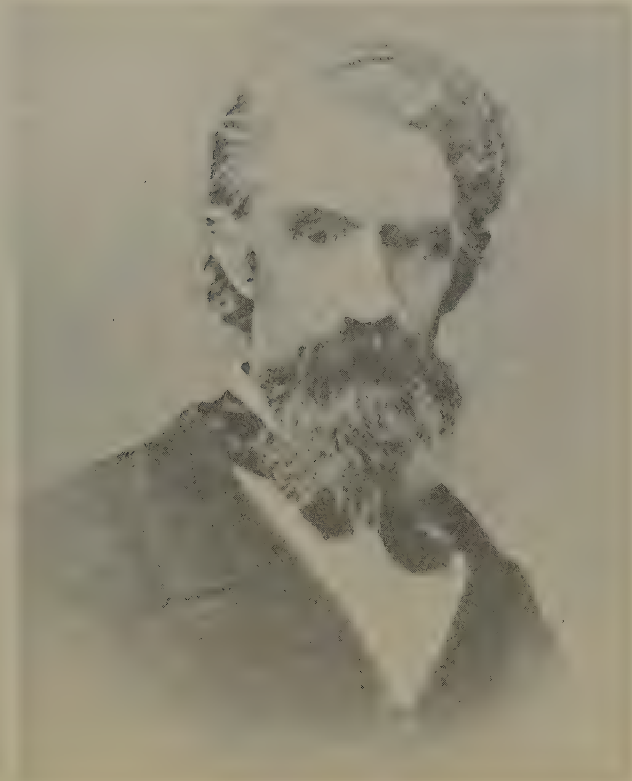
It followed that Dr. Green was eminently suited to become one of the first good educators in forestry in the United States. He initiated courses of study, wrote a manual for forestry in Minnesota (1898) and the book "Principles of American Forestry" (1908). Until the time of his death (1910) he continued the work of teaching and developing the Department of Forestry of which he was appointed Dean.

With two such prominent and energetic men, Andrews and Green, as leaders, the state of Minnesota was off to a very good start in forestry. Where General Andrews prepared the ground, laid the foundation, and awakened public interest, Dr. Green, as champion of forestry, wielded much influence, especially by virtue of his charming personality and numerous official connections, for he was president of the Minnesota Horticulture Society, member of the State Board of Forestry and of its Executive Committee and chairman of the Agricultural College Curriculum Committee.

Then followed rapid developments in recreation, protection of wildlife, erosion control, camp grounds, summer home sites, roads and waterways. Counties began to be paid for tree planting, and such favorable

Dr. Samuel Bowdlear Green

legislation was enacted as the passage of the fire prevention law of 1895, the creation of the Forestry Board 1899, and constitutional changes which resulted in State Forests in 1917, the Department of Conservation in 1925 and the State Conservation Commission in 1931. In 1903 the federal government added the Burnside State Forest of 20,000 acres, and there have been additions by donations, among which Governor Pillsbury gave 1,000 acres. Minnesota now ranks second in the area of state-owned forests with 2,011,270 acres.



Dr. John A. Warder

Dr. John A. Warder, 1812-1883, of Ohio and the Organization of the American Forestry Association

Dr. Warder was born near Philadelphia, Pennsylvania in 1812. His early life was spent in the suburban home called "Woodside," and he had the good fortune to be early inspired by his parents with a love of nature and he, early in life, formed a habit of close observation which enabled him to learn much about trees, plants and rocks. At times he was privileged to walk the woods with Audubon or Michaux or Nuttall, great naturalists who were occasional guests at his father's house.

In 1830 he moved with his parents to another "Woodside" near Springfield, Ohio. Here he took great interest in the study of anatomy, agricultural sciences and the promotion of education. He soon became a member of the School Board which often met at his home. After graduation from the Jefferson Medical College of Philadelphia, 1837, he began medical practice in Cincinnati. It is recorded that he became active in

most of the urban benevolent organizations. He joined the American Association for the Advancement of Science, served as president of the Ohio Horticultural Society and became a valued member of the Ohio State Board of Agriculture. Actuated by his love for country life and his deep appreciation of the charming views of Ohio's hills and woodlands he purchased in 1855 a part of the farm once owned by President Harrison at North Bend, where he lived, labored and wrote until he died. It is stated that his farms and orchards became an experiment station from which he sent many original papers for publication in the "Western Horticultural Review." Meanwhile he also prepared a report on flax culture for the U.S.D.A., edited DuBreuil's "Vineyard Culture" and prepared a manual on hedges and evergreens.

However, it is chiefly as a promoter of forest conservation and culture that he claims our notice. During his active life he had also seriously considered the great waste and evil results coincident to the harvesting of our forest resources. In 1873, after he had served as U.S. Commissioner to Vienna, and had submitted the report on the advanced state of forests and forestry there, he became a staunch conservation protagonist.

In 1875 he issued a call for a convention held in Chicago in order to form an American Forestry Association. A second meeting took place in Washington, D.C. the following year. Through much of Dr. Warder's efforts a group of Ohio citizens implemented another convention in Cincinnati 1882, which was followed by meetings in Rochester in June and in Montreal in September out of which evolved the American Forestry Association. (These gatherings are referred to by Dr. Hough as meetings of the American Forestry Congresses; see Journal of American Forestry 1:31, 64, 115, 1882-83.)

A great impetus toward action in the fields of forestry and conservation was supplied by an eminent German forester, Baron von Steuben, a descendant of a General of revolutionary fame, who had come to America for the 100-years' celebration of Yorktown. The Baron von Steuben was incidentally visiting relatives who lived in Cincinnati, where he vigorously deprecated the terrible misuse of our American forests. Dr. Franklin Hough considered that the Baron von Steuben visit and his remarks provided the first incidents which led to the call for the 1882 Cincinnati convention.

For this Cincinnati meeting it was Dr. Warder's comprehensive knowledge of forestry that obtained such varied subjects for the program. The delegates who came from every part of the U.S. and from Canada brought or sent a total of 85 papers on all phases of conservation, most of which could not be immediately read or published. We note that among the 73 in attendance were Gen. C.C. Andrews, Dr. B.E. Fernow, and N.H. Egleston, of Washington, D.C.

During the 1882 conventions a constitution was enacted, a president and 11 vice presidents elected—each vice president representing districts in U.S. and Canada—the usual officers were chosen and five committees appointed for reporting separately on experiment stations, forest fire injuries, methods of planting trees and on forestry education. The following sections were also established, each with a chairman and secretary: A - Uses of the Forests, Franklin B. Hough; B - Conservation

and forest practice, John A. Warder; C - Influences, Prof. Wm. Saunders, Ontario; and D - Education, N. H. Egleston, Washington D. C. Dr. Hough concluded as follows:

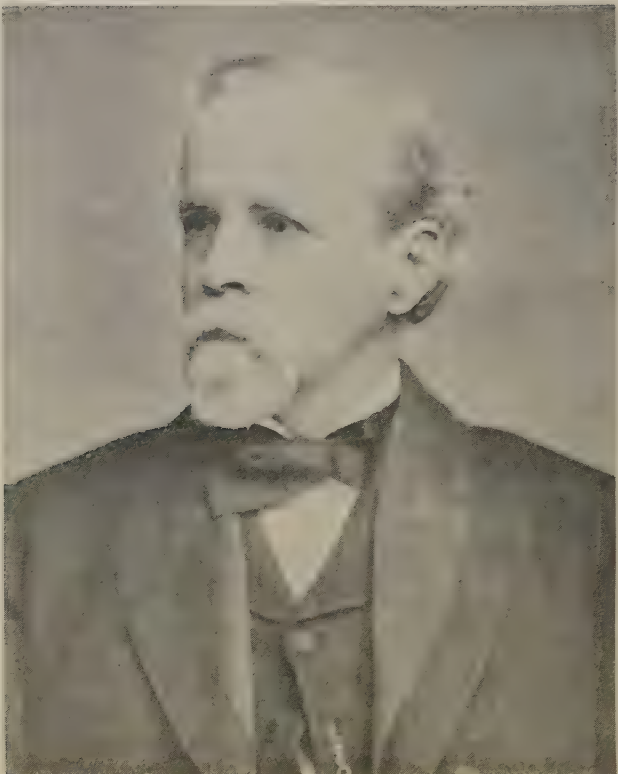
> "We cannot but regard this convention at Cincinnati as destined to result in having awakened public attention to the great importance of Forestry, for the welfare of the present and the future. It attracted the notice of active minds which had not previously realized the dangers from excessive exhaustion of our forest supplies, and the neglect of measures for their renewal; and it brought together from every part of the country men who had taken a deep interest in this question ... it will lead to the most important results."

In the course of his deep and intense concern for the promotion of forestry Dr. Warder wrote and published dozens of papers in various journals and periodicals on trees, windbreaks, plantings, forests and water supply, thinnings, trimmings and pruning of trees, etc. A partial list of 25 papers is given in the American Journal of Forestry 1:520, 1882-83.

Major John Fletcher Lacey of Iowa, 1841-1913.

Major Lacey was born at Martinsville, Va., and moved with his parents to Wheeling, West Virginia 1853. From there the family came to Iowa in 1855 and settled on a farm near Oskaloosa in 1856. The young Lacey endeavored to continue his education at the Drake's Academy. It was the old story of manual labor and farm work in the summers alternating with teaching and study in the winter months. However, the Civil War disrupted his program also. In the spring of 1861 he enlisted in Company H, the Third Iowa Infantry. He was soon taken prisoner at the Battle of Blue-Hills, Mo. After a parole and exchange of prisoners he re-enlisted in the spring of 1862, and was commissioned Sargeant Major. The following spring he was Acting Adjutant-General under Colonel Rice. Before the end of the war he had participated with distinction in five battles and two sieges. After his discharge in September 1865 he was admitted to the Bar, settled down for a law practice in Oskaloosa and married Martha Newell. One of his chief jobs was that of legal counsel for the Rock Island R.R., by virtue of which he came to write the first two volumes of the Railroad Guide. He and Mrs. Lacey made two trips to Europe, the first of which was in 1878. In 1884 he was elected to serve in the 51st Congress, and was re-elected to the 57th, 58th, and 59th Congresses. As a committee member on Forests and Conservation he traveled to observe conditions in the western U.S. and in Alaska. At the time of his death he had just been elected president of the Iowa Bar Association.

Major Lacey was pre-eminently a lawyer; but his career in Congress brought him credit and distinction; he became a tower of strength and good counsel in matters on conservation of forests, wildlife, and our natural resources generally, especially as a member of the Public Lands Committee. He drafted and prepared the law which set aside the Yellowstone Park; drew up the rules for its administration; lent his aid and



Major John Fletcher Lacey

influence in the creation of the Crater Lake, Yosemite, and the Petrified Forest parks. He was a pioneer and promoter of legislation for the protection of bird life, and the "Lacey Bird Law," as it is called, was the forerunner for protective legislation covering all migratory birds. In the words of Wm. T. Hornaday, "It prevented the illegal slaughter and sale of untold millions of game birds, and the rogues that this law brought to justice, if herded together would make a great army." At the very critical period when Congress wanted to annul the forest reserve act, it was Major Lacey's deep concern for the wise use of our forests that brought out his amendment providing for timber sales within these reserves if supervised by trained personnel. This action saved the life and assured the existence of our national forests. Quoting from his speech in Congress: "The practical question of today is how to undo the mistakes of the past; how to prevent them in the future. Agitation and discussions are necessary to call the attention of the people to the importance of maintaining, and at least partially restoring, some of the

primitive forests of this country. We must give up some part to nature in order to keep the remainder for ourselves."

It is now fitting for us to record excerpts from the appreciation this man received for his devotion to the cause of forestry and the conservation of wildlife and the natural resources:

From President Theodore Roosevelt's letter at Oyster Bay, N. Y., July 16, 1906; "It has been my privilege to be closely associated with you and to watch the many different ways in which, without any hope or expectation of personal reward, you have rendered efficient public service. I give utterance to the feelings of very many men when I express to you my cordial thanks and extend to you my earnest good wishes." In further appreciation of Major Lacey the president spoke; "I wish to congratulate this district in having in Congress a man who spends his best efforts for the welfare of the whole United States. I can ask Mr. Lacey to come to me, or I can go to him in matters of consequence to the nation, with the absolute certainty that he will approach it simply from the standpoint of public service."

From his associate, Hon. Ray who said; "He had a depth of human sympathy seldom surpassed, and his unfailing cheerfulness and loyalty to justice and right, made and kept friends through his entire life . . . and no man in the public life ever gave more cheerfully of his strength and time to secure useful legislation."

From the Cedar Rapids Gazette: "Even his most pronounced political opponent felt a deep-seated esteem for him, an esteem that could not be blotted by all the turmoil of heated political campaigns. He was one of the ablest of the old guard of Iowa Republicans, as uncompromising in his opposition to parties and principles in which he did not believe, as he was able."

From the Oskaloosa Herald: "Oskaloosa never had another citizen who won so much distinction in so many fields. In every walk of life he was alive to the best of the situation. He was observing, keen and witty, ever the life of the group about him . . . He was persistent and bitter in a fight, but never harbored a spirit of retribution; he respected the beliefs and principles of others."

From Father Loftus of the St. Mary's Church in Oskaloosa (Lacey was an Episcopalian): "John F. Lacey in his life and in his death has been visibly and singly dealt with of his God. He blessed him with a high purpose, an ambition to live a noble life. God blessed him in his search for material out of which to construct the edifice of that life... Lacey as he was before his God, the perfect masterpiece of the highest and noblest American Life."

Dr. Joseph Trimble Rothrock

Dr. Joseph Trimble Rothrock 1839-1922. Beginnings of Forestry in Pennsylvania

Dr. Rothrock, who became prominent as a pioneer and leader in the establishment of forestry in Pennsylvania was born 1839 at McVeyton, Penna. His long life was one of patriotic devotion to the service of his state, his country and to his fellow men. As a boy he attended school at academia and at the Freeland Seminary, Montgomery County. Later he graduated from the Lawrence Scientific School at Harvard with a Bachelor of Science degree and in 1867 from the Medical School at the University of Pennsylvania with an M.D. degree. He practiced medicine in Wilkes-Barre, and became a surgeon and chaplain in the Civil War, serving first as a corporal in the 131st Penna. Infantry and later as Captain of Company E in the 20th Cavalry. He was wounded at Fredricksburg and was known as a brave and able soldier.

Dr. Rothrock was a man of varied activities and experiences and made enviable records in many of them. Besides being a good soldier and a surgeon he was an explorer, botanist, lecturer and author, a university professor and at times a master navigator. As a lecturer under the Michaux grant in 1870 he vigorously set forth the needs of forestry in his state and nation. He was deeply devoted to life in the open. As Commissioner of Forestry he developed and fostered the idea of using the eastern mountains to relieve and to cure cases of tuberculosis. Voyaging in his own yacht along the Atlantic Seaboard, he observed and recorded botanical and biological observations. He was an ardent hunter of big game, especially in the forests of Maine and occasionally in Canada. It is recorded that in the light of the camp fires he kept the party in an uproar with tales of his experiences in college, the war, travels in Alaska, on the ocean and in Europe. From his contact with the forests of Germany and with nine months of study at the University of Strassburg, came the inspiration for the restoration of the forests of Pennsylvania.

It occurred to Mr. Wirt (see list of references) that there were two special incidents in Dr. Rothrock's life which have been determining factors in his development. While still a boy he and a companion were miraculously saved from drowning in a deep section of the "swimmin' hole" and when after the battle of Fredricksburg he lay seriously wounded in a hospital Abraham Lincoln came to his cot, lifted his hand and said, "God bless you young man, the country needs men like you." In a comparatively short time he was back home where he organized a troup of cavalry and shortly became the captain.

The chain of circumstances which tipped for him the scales away from medicine and to forestry are briefly told. He loved the forest, and knew many local areas. Asa Gray guided him as a student into the study of botany, and there was as we know a strong connection between plants and cures. It was while he studied botany in Germany that he learned the fundamentals of forest management. As a physician he realized the value of Pennsylvania's forest for the health of its citizens; in his western travels he had come to know the forests of this nation, he felt certain that the forest destruction going on in his own state would impair or destroy cities and industries, wildlife, water supply and all recreational values.

Though Dr. Rothrock never claimed to be a forester, it was by reason of his reading, contacts and keen observation that he grasped the fundamentals of forest management and its importance in the state economy and welfare. He never accused the lumbermen directly of forest devastation; rather he blamed the apathy and ignorance of the people and the legislators. He therefore gave himself to the fight to change that attitude and to awaken the public to action. In his official capacity he exhorted the Republicans of the state to provide means for the education and training of foresters and to enlist the interest of young men. This finally came about in the establishment of a Forest Academy at Mount Alto.

It was about the year 1885 that Dr. Rothrock started Pennsylvania on the way to State Forests, which in 1951 covered 1, 736, 000 acres.

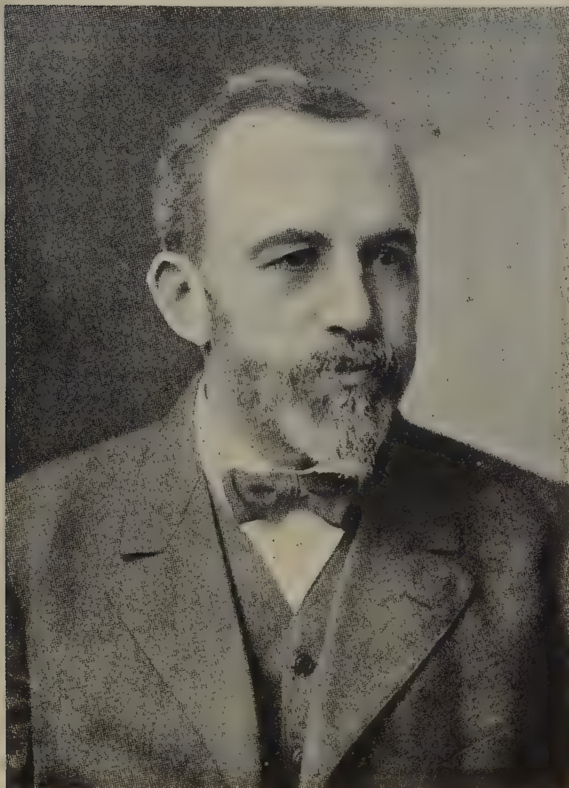
Dr. Rothrock was a man of vision and he had also the will and energy to do the work necessary to make those visions come true; he set the example which men of high caliber were proud to follow.

The attributes and accomplishments of this great leader in the forestry movement are well summarized on the memorial tablet erected in his honor at Mount Alto by his friends: Among those present at the dedication ceremony were H.S. Drinker, R.Y. Stewart, George B. Wirt, Joseph Illick, and C.W. Scoemaker.

> "Patriot, Soldier, Pioneer, Forester, Botanist, Sportsman, Physician, Educator, Author, Public Servant, Distinguished Citizen, Loving Husband and Father.
>
> The Father of Forestry in Pennsylvania, First Commissioner of Forestry of Pennsylvania. Active and devoted member of the Pennsylvania State Forest Commission from 1893 until his death. M.D., University of Pennsylvania, 1867. Professor of Botany at Pennsylvania State College and later at the University of Pennsylvania. A leader in the Conservation of our Forests and Streams. One of the Founders and a life-long Member and Officer of the Pennsylvania Forestry Association. Honorary Member of the Society of American Foresters. Founder and Promoter of the State Forest Academy and of the Mount Alto Sanatorium."

In his life he exemplified the typical traits and virtues of American manhood, and in his death he left us the memory and example of one who embodied in his character and life, "Whatsoever things are true, whatsoever things are honest, whatsoever things are just, whatsoever things are pure, whatsoever things are lovely, whatsoever things are of good report."

Dr. Rothrock is credited with the publication of 49 technical papers on forestry (Munns).



Dr. Filibert Roth 1858-1925
A Teacher and Leader in Michigan

Professor Filibert Roth, "Daddy Roth," as he was known to his students, was born in Würtemberg, Germany, April 20, 1858. He came to the New World with his parents after living thirteen years in an old forest and farm community. They settled first in Ann Arbor, Mich., but soon moved to Wisconsin. Three years later, when only sixteen, he evidently felt himself self-sufficient and capable to such a degree that he went west to the east flank of the Rockies, where prairies and forests meet. It was the call of the frontier and it never left him. For eight years, during the great formative years of his life, and the life of the West as well, he lived the life of a frontiersman, hunting buffalo, trapping wolves, and ranging with cattle from Texas to Montana. He witnessed the quelling of numerous Indian outbreaks. Being deeply impressionable, this experience never left him, and he obtained therefrom a realistic understanding

of American development. He actually lived and took part in the great transition from unhindered exploitation to control and management of our natural resources within the public domain.

In 1882 he returned to Wisconsin, worked in the woods and taught school, entered the University of Michigan in 1886 and graduated in 1890. In 1890 he married Clara Hoffman. After graduation he was asked to remain as a teacher in mathematics. But, fortunately for forestry, Dr. B.E. Fernow, at that time head of the U.S. Division of Forestry, prevailed on him to become his assistant in Washington. In this capacity he eagerly studied forestry, reading the German publications.

Under Fernow he performed several creditable pieces of work, among them the very first bulletin treating of strength and microscopic structure of our southern pines. When the School of Forestry was opened at Cornell University and placed in charge of Dr. Fernow, Roth naturally followed him there. It was the beginning of a great career as a teacher of forestry. When this school was discontinued, Roth was for a short period made superintendent of the National Forest Reserves in the General Land Office. When a School of Forestry was opened in Ann Arbor, Mich., he was asked to come there and be the leader.

As the leading technical forester of Michigan he was expected to take an active part in urging forestry measures for the state, and was made State Forest Warden in charge of two state reserves. The Hon. Chas. W. Garfield, who for years had vigorously urged forestry for the state, said: "When Roth came, he put the spirit of enthusiasm and training into our efforts, and we seemed fairly to bound along."

In 1908, mainly as a result of his untiring efforts to expose the evils attending the disposal of the state's tax-delinquent lands, he was appointed to the Commission for the Investigations of these lands. It also resulted in a law which allowed such lands to become state reserves. To him the need of forestry was so obvious that he could see no reason for any delay, and he was so eager to see it go forward that for several years he gave of his teaching salary to support the young man who was his instructor and assistant in forestry at the University of Michigan.

This same spirit and unquenchable flame operated also in the class room. It transformed young men into enthusiastic devotees of forestry, and, since he was by every utterance a personification of all that is best in forestry, liking him, they liked the profession. The success that Michigan graduates in forestry have demonstrated in silvics, management, silviculture, forest surveys, etc., is attributable largely to the personality and enthusiasm of Dr. Roth. He recognized that silviculture was the flesh and bone of forestry and was very important as a forest builder; that logging techniques, recreational engineering, wood technology and preservation also would come to the fore in due time. His wide experience, not only in political matters, but also in the virgin forests, which was preceded by his boyhood in the well-cared for forests of southern Germany, gave Roth a sound background for his teaching that is almost unparalleled. He knew forestry instinctively; he felt it; all his life it was a part of him. He correctly evaluated the weight of forestry measures unthinkingly. He saw clearly what should be the course and line of action. (Collingwood 1926)

Dr. Roth held that it is the privilege and duty of a teacher to look

forward with optimism and enthusiasm; that no one who had such a noble cause as forestry should be too proud to fight for it. For years he gave freely of his strength that the people of Michigan might realize their forest heritage before it was entirely squandered. His courage and optimism seem d dauntless in the face of odds which downed many other forest fighters. There were times, especially during his last years, when he confessed his disappointment, but always he maintained the faith that the work which he had helped to foster would be accepted and developed by the State of Michigan. He took great pride that "his boys" were taking positions of leadership within the State. The impact of his life extended to every part of North America and to the farthermost parts of the world. During his very busy life he wrote 55 articles (Munns) on forestry for the journals and the press, two excellent manuals for the practice of forestry in Michigan and two texts for students of forestry; First Book of Forestry (1902), and Forest Valuation (1916). Mr. G.H. Collingwood, editor of American Forests, also wrote this tribute:

"Filibert Roth—An Appreciation.

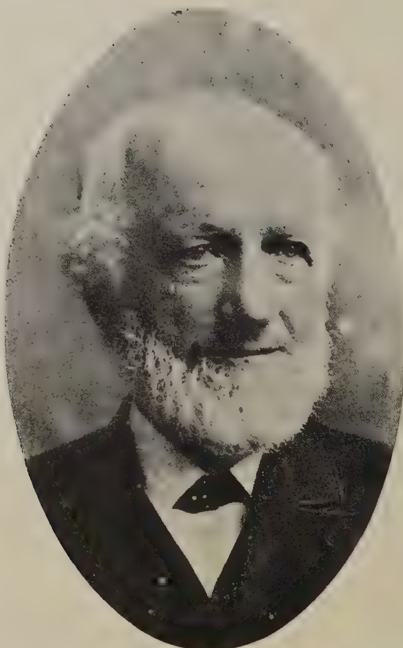
"One of the pioneers of American forestry has passed on. The man who tersely signed himself "Roth" and whose students lovingly called "Daddy" is no more. The news of the death of Filibert Roth on Friday, December 4, 1925 reached Washington barely in time to be included in this issue of American Forests and Forest Life. As this magazine goes to press no word has been received as to the cause of his death, although it is known that on the fourth of last August he suffered a shock from which he wholly did not recover. His friends have realized for several months that his health was failing and with this news they will mark the passing of a splendid man."

Dr. Franklin B. Hough 1820-1885.
New York State Awakens to Forestry

In the life and activities of Franklin B. Hough who pioneered in forestry in his native Empire State we begin a trace of pro-forestry sentiment emerging from state to national level. This came about by Dr. Hough's contacts with men of national prominence and the American Society for Advancement of Science.

Dr. Franklin B. Hough was born 1820 at Lowville in the State of New York. He graduated from Union College in 1843 and Western Reserve 1848. His special fields of interest were geology and botany, and in the pursuit of these he traveled widely amassing considerable collections. His extensive journeys on foot did much to build an exceptionally good physique. Meanwhile, his numerous articles in the press on his observations were full of enlightenment and interest. He had a very good memory so that new facts with him fell easily into place with others he had gained.

In referring to Dr. Hough's characteristics his biographer, from long personal acquaintance writes: "He had a very remarkable power



FRANKLIN B. HOUGH

of concentrating his mental energies on one subject, and therefore made himself master of it with unusual rapidity. In this way he obtained a good working knowledge of botany, geology and minerology; he became a good compiler of forest statistics, especially since he was one of the State census reporters. And, being conscientiously thorough in his work, he spared no labor himself to bring his statements down to the last degree of certainty."

Naturally his work came to the attention of others of kindred interests elsewhere, and acquaintance often ripened into warm friendship. Among the strong personal friends of early days were Louis Agassiz, John Newberry, Spencer F. Baird and others who have left a lasting influence in their respective fields of science.

After his return from service in the Civil War as a surgeon he devoted himself entirely to scientific and literary work, and in the years which followed wrote many reports and articles of importance.

Such was the make-up of the man who was destined, in the self-imposed task, to stem the tide of public and private misuse of our forests, and to formulate and carry into execution plans which initiated better

management, by the establishment of the United States Division of Forestry (now called the Forest Service) in the U.S. Dept. of Agriculture.

To understand some of the obstacles he had to contend with we must appreciate that at the first settlement by white men the policy had been to destroy the forests in order to prepare the land for agriculture. The course of general forest destruction which had begun was continued also by the demand for lumber, and so imbued was the public mind with the blind belief that the maxim which had guided father and grandfather was still operative, that the devastation continued. A few thinking minds came to appreciate the fact that this destruction should stop; that the forests which were left should be husbanded with due care and regard for the future.

During his busy life Dr. Hough was twice superintendent of the New York Census. By comparing consecutive reports he noticed a great falling off in timber supplies. This led him to question; How long will the supplies last? What then?

Finally in August, 1873, Dr. Hough prepared a paper entitled "The Duty of Government in the Preservation of Forests," and read it before the American Association for the Advancement of Science, at its meeting in Portland, Maine. The opening paragraph vividly pictures (1) the consequences of deforestation, (2) the need for laws to regulate and protect the growth of wood, and (3) various measures which the state might adopt for the better use of its forests. He stated that such questions are not limited to the state but are vital to the nation generally. He recommended that the U.S. Congress appoint a special committee which should impress upon the several states' legislative bodies the great importance of this subject.

He recommended to the A.A.A.S. the draft of a bill which carefully considered various aspects of public interests and private rights; and on the whole was adapted to secure the benefits desired. The reading of the paper was followed by a general discussion and the following members were selected as the special committee referred to above: Franklin B. Hough, Lowville, N.Y., Chairman; George B. Emerson, Boston; Prof. Asa Gray, Cambridge, Mass.; Prof. J.D. Whitney, San Francisco; Prof. J.S. Newberry, New York City; Hon. Lewis H. Morgan, Rochester, N.Y.; Col. Charles Whittlesey, Cleveland; Prof. William H. Brewer, New Haven; and Prof. E.W. Hilgard, Ann Arbor. The Committee shortly convened and the first two named above were appointed a subcommittee which prepared a memorandum and brought the subject before Congress.

This plan was cordially approved by President Arthur and the memorial submitted by the subcommittee was transferred by him to Congress in a special message. The matter was referred by both houses to the Committee on Public Lands. But there was much delay, debate and many months of anxious waiting before Congress took action. Amendments came also—one calling for the appointment of a qualified person to make inquiries pertaining to forestry.

It evolved that forestry was made a Division of the Department of Agriculture, instead of a Commission of Forestry as first intended. Dr. Hough was made its first Chief, receiving his commission from Hon. Fredrick Watts, then Commissioner of Agriculture, and was given an appropriation of $3,000 per annum.

In the performance of his duties Dr. Hough had to overcome many obstacles—delays by the American Association; the ignorance and indifference of the public; the apathy and direct opposition of influential timber owners; the restrictions on offical printing; a ridiculously low appropriation and a lack of funds for clerical help.

Nevertheless, he entered upon his service and finished his first Report upon Forestry so as to deliver it to the Commissioner of Agriculture on the 8th of December, 1877. It was printed and distributed early the next year. The matter withheld from the first report on account of limitations by the Printing Committee, appeared in the succeeding reports.

During his extremely busy life Dr. Hough wrote three lengthy Government reports, advocating the active prosecution of matters in forestry for the nation, stressing conservation and education of the public and technical training for the personnel. He gave a great impact to the formation of the U.S. and the New York State Forestry Associations, in which he occupied offices as president and secretary. One of his most valued contributions is his editorial work on the very first technical publications on forestry in America, the American Journal of Forestry for 1882 and 1883. This has become an invaluable source concerning the personnel in U.S. Forestry during the formative years.

In addition to these reports already mentioned Franklin B. Hough, according to Munns, wrote twenty technical papers on forestry and allied subjects.

Dr. Bernard Eduard Fernow, 1851-1922
U.S. Chief Forester and Educator

Dr. Fernow, who became one of the greatest leaders in the establishment of forestry on a national level in the United States, was born in Posen, a province of Germany, 1851. He had the grounding of a very good education and knowledge of forestry. He came to the Philadelphia World Exposition in 1876, remained in this country, sought employment here and early maintained a home in Brooklyn. Eventually he made contact with the Cooper and Hewitt Company which operated smelters in New Jersey and Pennsylvania, became the manager of their forest areas and the smelter as well. In the course of these activities he learned much about the composition, growth and deterioration of the Eastern U.S. forests. After a period of years he became strongly conservation minded, wrote articles and delivered speeches in which he urged the protection, improvement and better management of our forests. It was at the September meeting of the American Forestry Association in Montreal where he read an excellent paper, that he made a telling impression and gained the confidence and friendship of other leading American and Canadian conservation-minded men. Fernow had at one time studied law at Königsberg, and his writings and speeches display the concise statements, the marshalling of facts, and the attitude of pleading a case. There is no looseness of expression. He was a clear and emphatic public speaker.

DR. B. E. FERNOW
DEAN OF THE FACULTY OF FORESTRY, UNIVERSITY OF TORONTO, AND VICE PRESIDENT AMERICAN FORESTRY ASSOCIATION

By virtue of his writings about forestry and conservation and the friendship with Dr. Hough and other like-minded leaders he came to the notice of President Cleveland. This prepared the way for his appointment, upon the retirement of Dr. Hough (1886), as Chief of the Division of Forestry in the U.S. Department of Agriculture.

While Fernow was chief of this division he became confronted with the huge tasks of forest appraisal, forest reconnaissance, stock-taking of resources, surveys, the preparation of charts and maps, statistical tables and other weighty responsibilities. Working always with less than a dozen helpers he performed his duties with the facilities available. He wrote more than he could inaugurate. He was never satisfied, and not until he became editor-in-chief of the Forest Quarterly was he able to tell, and to show, with materials at hand, what he really knew.

During the twelve years as Chief Forester he laid the foundations on which were built the beginnings of the U.S. Forest Service. In 1887 he prepared the resolution for Congress concerning all federal timber lands, containing the provision (by Major Lacey) for the sale of timber and management by technically trained personnel. At the beginning of the

present century he initiated the first reforestation project under the federal government for the planting of the sandhills in Nebraska.

In 1888 Fernow organized an extensive program for the investigation of the properties of American woods, with a view toward determining their suitability for various uses. Dr. Filibert Roth, who was then his valuable assistant conducted the study and prepared the report on "The Southern Yellow Pines," giving their various mechanical properties, microscopic structure and distinguishing characters. Timber testing machines were later installed at the Yale School of Forestry, out of which evolved the staff and equipment for the U.S. Forest Products Laboratory in Madison, Wisconsin, 1910.

As long as he lived Dr. Fernow was an initiator and leader in forestry education. He was one of the first to give lectures in technical forestry at the Universities of Nebraska, Wisconsin and at Amherst, at Pennsylvania State College, and at Yale School of Forestry.

In 1898 Fernow resigned from the U.S. Forest Service and was called to Ithaca, N.Y. as Dean and Director of the School of Forestry at Cornell University where he served with distinction until the call came for him to take charge of the organization of a school of forestry in Toronto, of which he was the Dean from 1907 until his retirement by reason of age in 1919; remaining as Dean Emeritus until his death in 1922. The circumstances which brought him to Canada, no doubt, center around the misunderstandings and apprehensions harbored by the public and the New York legislators in regard to the removal of some timber within the State Park at Axton, N.Y. Also the fact that Fernow in 1903 had delivered a course of lectures at Queens University in Canada. Before moving to Canada he had spent the winter of 1906-7 assisting and teaching at the initiation of the Pennsylvania State School of Forestry.

In Canada Dr. Fernow early saw the necessity of stock-taking of the forest resources, and for more adequate protection from losses by fire. As a chairman of the Forestry Committee he was instrumental in obtaining forest surveys in Nova Scotia, British Columbia, and Saskatchewan, and in 1921 an inventory of Ontario's forest resources was in progress. He also studied forest legislation in progress in the United States and reported to the Canadian Government. He kept in close contact with forestry activities in all parts of the continent and exerted a profound influence on its development. It was a fortunate situation that he remained as editor-in-chief of the Forestry Quarterly until this series was succeeded by the Journal of Forestry beginning 1917.

As a teacher Fernow saw the school at Toronto grow from a score to over fifty students, and he gathered about him young men on whom he placed his imprint. They were proud of him; they could trust him to the uttermost; they loved him. Dr. Fernow was one among thousands and his personality was his greatest and finest quality, for he was always kind, always courteous, tolerant and unselfish. No matter how hard the toil, or how much discouragement, the body, mind and spirit remained buoyant, and these qualities reached their supreme expression in his last illness.

The value of Dr. Fernow's contribution to the cause of forestry on this continent has been fully recognized and appreciated; he received the Honorary Doctor of Laws at the University of Wisconsin in 1896, at

Queens University in 1903, and by the University of Toronto in 1920. The technical articles listed to his credit number 196 (Munns), with several circulars and bulletins, and two textbooks—The History of Forestry (1907) and Economics of Forestry (1902).

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FOREST PRODUCTS AND INCOME TAXES

Dayton Countryman[1]
Lawyer, Nevada, Iowa

It is with a great deal of pleasure and respect that I write this paper for Professor George B. Hartman, Head of the Department of Forestry at Iowa State University, Ames, Iowa. Professor Hartman for years devoted a good part of his life to the business and commercial field of forestry and for that reason I believe that "Forest Products and Income Taxes" may properly be a part of the issue of the Journal of Science dedicated to him. Nevertheless, I shall always remember Professor Hartman as a man with a deep and abiding interest in his fellow man and one who always remembered and followed the careers of many students who had the privilege of being associated with him.

It is significant that in 1949 a committee of the Society of American Foresters was appointed; they conceived and developed a handbook[2] in February of 1953, which was approved by the Bureau of Internal Revenue, in which the committee set forth certain beliefs, namely:

> "(1) That forest practices on small holdings would be improved if the owners were informed of their actual income-tax obligations and opportunities.
>
> "(2) That many, if not most, small forest-land owners pay more in income taxes on timber sold or harvested than the law requires.
>
> "(3) That overpayment detracts from the economic incentive to practice forestry."

In the introduction of this same handbook the committee said,

> "It is unfortunate both for the timber owner and for the community if timberlands are not fully utilized for production of forest products because of a mistaken belief that the proceeds will be largely taxed away. It is equally unfortunate if owners fail to protect, maintain, and improve their timber property because they do not understand that expenditures may be capitalized or treated as deductible expenses.
>
> "A clearer understanding of income-tax procedures should benefit the taxpayer financially and should at the same time encourage better forest management. It is hoped that savings realized through use of correct procedures in reporting timber receipts and expenditures will act as incentives for timber owners to grow more timber, to protect it better, and to utilize it more wisely."

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[1] Former Attorney General of Iowa admitted to practice before: Supreme Court of Iowa and all Iowa State Courts; Supreme Court of the United States of America; and the United States Treasury Dept. B.S. in Forestry and LLB in Law.

[2] Williams, 1953, The Small Timber Owner and his Federal Income Tax. Agr. Handbook No. 52, U.S. Dept. of Agriculture, p.III.

In our free enterprise system of government, profit is one of the motivating forces in the production of the many material things that we now have. Money left after taxes, sometimes referred to by employees as take-home-pay, is equally important. A quick look at the Federal Income Tax Tables for 1959[3] shows that each taxpayer having taxable income will pay at least twenty cents in the form of income taxes on every dollar of taxable income earned. If he is a single taxpayer with a net taxable income of $16,000 to $18,000 he will pay out fifty cents on every dollar earned in this bracket. If this $16,000 to $18,000 were reduced by capital gains treatment or by Code Section 1231 treatment by 50% it would then be in the $8,000 to $10,000 bracket and the rate for a single person for income in this bracket would be thirty-four cents on every dollar. Though this is much above the average income it does point out the importance that income taxes have on the money that is left after taxes.

There are three general methods of treating income from timber.[4]

1. If the property is held for investment, the gain or loss is a capital gain or loss and the property is a capital asset under Code Section 1221.
2. If the property is used in the taxpayer's business, was held for more then six months, and the taxpayer is not engaged in the business of selling timber, the gain or loss is a Code Section 1231 gain or loss.
3. If the taxpayer is in the business of selling timber, the gain or loss is an ordinary gain or loss and the property is neither a capital asset nor a Section 1231 asset.

With the 1954 Internal Revenue Code a relief provision was designated as Code Section 631, which provides that in certain cases the cutting of standing timber and the receipt of timber royalties result in Section 1231 gains and losses.

Code Section 631(a) in effect entitles the owner of timber to capital gains treatment on the increase in value from the time the timber was acquired until the first day of the year in which he cuts it. Similar treatment is accorded a vendee or lessee having a contract right to cut the timber.

> "Section 631(a) Election to Consider Cutting as Sale or Exchange.[5] —If the taxpayer so elects on his return for a taxable year, the cutting of timber (for sale or for use in the taxpayer's trade or business) during such year by the taxpayer who owns, or has a contract right to cut, such timber (providing he has owned such timber or has held such contract right for a period of more than six months before the beginning of such year) shall be considered as a sale or exchange of such timber cut during such year. If such election has been made,

[3] How to Prepare your Income Tax Return on Form 1040, 1959.

[4] Prentice-Hall, 1960, Federal Tax Guide, Sec. 5302.

[5] Internal Revenue Service, Publ. No. 329-3, Part I of Title 26, 1954, Code of Federal Regulations, pp. 222-223.

gain or loss to the taxpayer shall be recognized in an amount equal to the difference between the fair market value of such timber, and the adjusted basis for depletion of such timber in the hands of the taxpayer. Such fair market value shall be the fair market value as of the first day of the taxable year in which such timber is cut and shall thereafter be considered as the cost of such cut timber to the taxpayer for all purposes for which such cost is a necessary factor. If a taxpayer makes an election under this subsection, such election shall apply with respect to all timber which is owned by the taxpayer or which the taxpayer has a contract right to cut and shall be binding on the taxpayer for the taxable year for which the election is made and for all subsequent years, unless the Secretary or his delegate, on showing of undue hardship, permits the taxpayer to revoke his election; such revocation, however, shall preclude any further elections under this subsection except with the consent of the Secretary or his delegate. For purposes of this subsection and subsection (b), the term 'timber' includes evergreen trees which are more than six years old at the time severed from the roots and are sold for ornamental purposes."

"Section 631(b) Disposal of Timber with a Retained Economic Interest.[5]—In the case of the disposal of timber held for more than six months before such disposal, by the owner thereof under any form or type of contract by virtue of which such owner retains an economic interest in such timber, the difference between the amount realized from the disposal of such timber and the adjusted depletion basis thereof, shall be considered as though it were a gain or loss, as the case may be, on the sale of such timber. In determining the gross income, the adjusted gross income, or the taxable income of the lessee, the deductions allowable with respect to rents and royalties shall be determined without regard to the provisions of this subsection. The date of disposal of such timber shall be deemed to be the date such timber is cut, but if payment is made to the owner under the contract before such timber is cut the owner may elect to treat the date of such payment as the date of disposal of such timber. For purposes of this subsection, the term 'owner' means any person who owns an interest in such timber, including a sublessor and a holder of a contract to cut timber."

The term "economic interest" is defined in the Regulation as follows: An economic interest is possessed in every case in which the taxpayer has acquired by investment, any interest in standing timber and secures, by any form of legal relationship, income derived from the severance and sale of the timber, to which he must look for a return of his capital.

Section 631 may be applied to numerous transactions.[6] Five of the most common situations are set out here in order to show the benefits that are obtained through its use.

Example One. Mr. Jones is a farmer who has a ten acre tract of timber on his land. He has owned the land for twenty years and wishes to sell the timber. His best solution is to make an outright sale of the

[6] 13 Arkansas Law Review, Winter 1958-59, pp. 48-49.

timber to another person. There is no doubt that he will be able to take capital gain on the profits, without applying Section 631.

Example Two. Mr. Brown is an attorney who for several years has been buying land as an investment. He has held all of the land for the requisite holding period under the statute. He wishes to retire and to obtain a steady income from the cutting of timber on his land. He should enter into a contract with a lumber company or a logger, under which the timber on his land will be cut on a selective basis. Title to the timber should remain in Mr. Brown until the timber is cut and his proceeds should be conditioned upon the severance. With this contract Mr. Brown will be able to realize a steady income from his land for many years and all of this income will be treated as a capital gain under 631(b).

Example Three. Mr. Clark owns 10,000 acres of timber which cost him $100,000. He wishes to cut this timber and sell it to various lumber companies. He has owned all of the timber for several years. His present depletion basis is $10 per M feet. The market value of the timber on the first day of the year in which it is to be cut is $200,000 ($20 per M feet). He should file notice with the Commissioner that he elects to take advantage of 631(a). If he cuts 1,000 M feet during the first year, he will realize a capital gain of $10 per M feet, or $10,000. He must pay tax on this $10,000 capital gain whether he sells the logs in that year or not. When he sells the logs, their cost in determining his profit is $20,000 plus his cutting costs. All receipts from the sale in excess of $20,000 will be treated as ordinary income.

Example Four. Mr. Black is in the business of logging timber. The owner of a 1,000 acre tract of timber wishes to contract with Mr. Black to cut it. The owner, however, wants to share to some extent in the profits which will be realized from the sale of the logs after the timber is cut. Mr. Black should enter into a contract under which he will pay the owner a set rate per M feet as the timber is cut. There should also be enough time allowed for performance so that he may hold the contract right for the period of time prescribed in 631(a). If the contract calls for Mr. Black to pay the owner a rate of $10 per M feet, and during the time it is held by him before performance the value of the timber rises to $12 per M feet. Mr. Black will realize a capital gain of $2 per M feet. The owner may share in the profits from log sales to third parties by contracting to this effect. This does not affect Mr. Black's absolute right to cut the timber at $10 per M feet and sell it, even though the owner may share in the profits of the sale.

Mr. Black may also realize a capital gain by assigning his interest to another party, but retaining such an economic interest that he will realize profits only from the severance of the timber. He may do this under 631(b) and his holding period would be computed with reference to the date of disposal rather than the year of cutting as in 631(a).

Example Five. Mr. White on January 1, 1958, bought 50 acres of timber for $1,000 at a forced sale. The depletion basis of the timber is $5 per M feet. Mr. White wishes to get an immediate return on his investment, but wants to take a capital gain treatment on such return. He contracts with a logger to cut the timber after July 1, 1958, at a rate of $10 per M feet, payable as the timber is severed. The logger is to make an advance payment of $1,000 to Mr. White at this time, which is

to be returned if the logger does not remove 100 M feet of timber from the property. Mr. White may treat this return of his investment as a capital gain under 631(b), since it is not earned until the cutting begins, and therefore, after the timber has been held for six months.

In conclusion it can be said that the many types and kinds of timber producers, owners, and contractors now have a method of receiving a certain measure of income tax relief under certain circumstances and that it will serve the best interest of government, the industry as a whole, and both the big and small timber producer to seek competent advice in the field of income taxation of forest products.

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A SIMPLIFIED METHOD OF COMPUTING CORDWOOD VOLUMES IN THE WOODS

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Frequently the practicing forester is faced with the problem of estimating the cordwood volume of individual trees or stands of trees in the woods without the aid of volume tables, basal area factors, or other means of converting the easily obtained measurements of height and diameter breast height into cords, the standard unit of measure in commerce.

When he is faced with this problem, the practicing forester or woodsman usually bases his estimation on personal experience and judgement. He generally considers two things in arriving at his estimate of the volume in standard cords:

1. The average size of the trees and the number of trees he feels it will take to make a truckload of pulpwood.

2. The number of cords of wood that he has learned it takes to make a truckload.

If the estimator wants to know the number of trees per cord, he mentally divides the number of trees he feels it will take to make a truckload by the number of cords in his imaginary truckload. If he wants to know the number of cords per acre, he tries to visualize the number of truckloads he can cut per acre, or he divides the number of trees per acre by the number of trees per cord.

A fairly precise method for estimating the cordwood content of individual trees has been devised by the author based on an observation that the basal area of a tree at DBH can be approximated by a single summation:

$$\text{Basal area} = \frac{\text{summation of } 2'' + 3'' + 4'' + \ldots + \text{DBH}}{100}$$

Thus, for a tree 8'' in diameter at breast height the summation factor equals

$$\frac{2'' + 3'' + 4'' + 5'' + 6'' + 7'' + 8''}{100} \quad \text{or } 0.35$$

Table 1 shows the comparison between basal areas and the summation factors computed for trees from 2'' to 20'' DBH.

Table 1. Comparison of basal area and summation factor of trees from 2" to 20" in DBH.

DBH	Basal area (sq. ft.)	Summation factor
2"	0.02	0.02
3"	0.05	0.05
4"	0.09	0.09
5"	0.14	0.14
6"	0.20	0.20
7"	0.27	0.27
8"	0.35	0.35
9"	0.44	0.44
10"	0.54	0.54
11"	0.66	0.65
12"	0.78	0.77
13"	0.92	0.90
14"	1.07	1.04
15"	1.23	1.19
16"	1.40	1.35
17"	1.58	1.52
18"	1.77	1.70
19"	1.97	1.89
20"	2.18	2.09

The summation factors are easy to determine at any time they are needed. The cordwood content of an individual tree can be estimated with the following equation:

$$\text{Cords} = \frac{\text{Summation factor} \times \text{Total height} \times 5}{1,000}$$

As an example, suppose the 8" tree, whose summation factor was found to be 0.35, has a total height of 55 feet. Then,

$$\text{Cords} = \frac{0.35 \times 55' \times 5}{1,000} = \frac{96.25}{1,000} = 0.096 \text{ or } 0.10.$$

Thus a tree having a DBH of 8" and a height of 55' would be expected to yield 0.10 cord of stacked wood.

A tabulated comparison of volumes computed by the author's summation method with volumes actually measured from prepared cordwood trees can be easily seen in Volume Tables 1 to 4, published by Cary (1939) and in Volume Table 5 published by Slocum and Miller (1953). The volume tables apply to a variety of species of conifers and hardwoods native to eastern United States.

Volume Table No. 1. White pine in cords.
(Cords by the summation method in parenthesis.)

Diameter breast high (inches)	Total Height of Tree - Feet 30	40	50	60	70	80	90
5	.03 (.02)	-	-	-	-	-	-
6	.03 (.03)	.04 (.04)	.05 (.05)	-	-	-	-
7	.04 (.04)	.05 (.05)	.07 (.07)	.09 (.08)	-	-	-
8	.05 (.05)	.07 (.07)	.09 (.09)	.11 (.10)	.13 (.12)	-	-
9	.07 (.07)	.09 (.09)	.11 (.11)	.13 (.13)	.16 (.15)	-	-
10	-	.11 (.11)	.13 (.13)	.16 (.16)	.19 (.19)	.22 (.22)	-
11	-	.13 (.13)	.16 (.16)	.19 (.19)	.23 (.23)	.26 (.26)	.30 (.29)
12	-	.15 (.15)	.19 (.19)	.22 (.23)	.27 (.27)	.31 (.31)	.35 (.35)
13	-	.17 (.18)	.22 (.22)	.26 (.27)	.31 (.31)	.36 (.36)	.40 (.40)
14	-	-	.25 (.26)	.30 (.31)	.34 (.36)	.41 (.42)	.45 (.47)
15	-	-	.28 (.30)	.34 (.36)	.40 (.42)	.46 (.48)	.51 (.54)

Cary, Austin. 1939. Woodsman's Manual. The Harvard University Press.

Includes volume of tree above $\frac{1}{2}$ foot from ground and up to 4" diameter in the top. (From State Forester of Massachusetts)

Volume Table No. 2. Spruce in cords of rough wood.
(Cords by the summation method in parenthesis.)

Diameter breast high (inches)	Total Height of Tree - Feet 40	45	50	55	60	65	70	75	80
6	.04 (.04)	.04 (.04)	.05 (.05)	.06 (.05)	-	-	-	-	-
7	.06 (.05)	.06 (.06)	.07 (.07)	.08 (.07)	.09 (.08)	-	-	-	-
8	.07 (.07)	.08 (.08)	.09 (.09)	.10 (.10)	.12 (.10)	.13 (.12)	-	-	-
9	.09 (.09)	.10 (.10)	.12 (.11)	.13 (.12)	.14 (.13)	.16 (.14)	-	-	-
10	.11 (.11)	.12 (.12)	.14 (.13)	.16 (.15)	.17 (.16)	.19 (.18)	.20 (.19)	.22 (.20)	-
11	-	.15 (.15)	.17 (.16)	.19 (.18)	.20 (.19)	.22 (.21)	.24 (.23)	.26 (.24)	.28 (.26)
12	-	.18 (.17)	.20 (.19)	.22 (.21)	.24 (.23)	.26 (.25)	.28 (.27)	.30 (.29)	.32 (.31)
13	-	.21 (.20)	.23 (.22)	.25 (.25)	.27 (.27)	.30 (.29)	.32 (.31)	.34 (.34)	.37 (.36)
14	-	-	.26 (.26)	.29 (.29)	.31 (.31)	.34 (.34)	.36 (.36)	.39 (.39)	.42 (.42)
15	-	-	-	.32 (.33)	.35 (.36)	.38 (.39)	.40 (.42)	.43 (.45)	.47 (.48)
16	-	-	-	.36 (.37)	.39 (.40)	.42 (.44)	.45 (.47)	.48 (.51)	.52 (.54)
17	-	-	-	.40 (.42)	.43 (.46)	.46 (.49)	.50 (.53)	.54 (.57)	.59 (.61)
18	-	-	-	.45 (.47)	.48 (.51)	.50 (.54)	.55 (.59)	.59 (.64)	.64 (.68)
19	-	-	-	.49 (.49)	.52 (.54)	.56 (.58)	.60 (.63)	.65 (.67)	.70 (.72)
20	-	-	-	.52 (.55)	.57 (.60)	.62 (.65)	.66 (.70)	.72 (.75)	.77 (.80)

Cary, Austin. 1939. Woodsman's Manual. The Harvard University Press.

Based on 2500 trees cut in Maine, New Hampshire, and New York; 4" top.

Volume Table No. 3. New England hardwoods in cords.
(Cords by the summation method in parenthesis.)

Diameter breast high (inches)	Total Height of Tree - Feet						
	20	30	40	50	60	70	80
3	.009 (.005)	.011 (.01)	.015 (.01)	.018 (.01)	-	-	-
4	.015 (.01)	.019 (.01)	.024 (.02)	.029 (.02)	-	-	-
5	-	.031 (.02)	.034 (.03)	.043 (.04)	.051 (.04)	-	-
6	-	-	.048 (.04)	.060 (.05)	.072 (.06)	.081 (.07)	-
7	-	-	.063 (.05)	.079 (.07)	.095 (.08)	.113 (.09)	-
8	-	-	.078 (.07)	.101 (.09)	.122 (.10)	.140 (.12)	.153 (.14)
9	-	-	.095 (.09)	.125 (.11)	.149 (.13)	.168 (.15)	.184 (.18)
10	-	-	-	.151 (.13)	.179 (.16)	.199 (.19)	.217 (.22)
11	-	-	-	.179 (.16)	.212 (.19)	.235 (.23)	.252 (.26)
12	-	-	-	.210 (.19)	.251 (.23)	.276 (.27)	.294 (.31)
13	-	-	-	.246 (.22)	.292 (.27)	.324 (.31)	.343 (.36)
14	-	-	-	.286 (.26)	.338 (.31)	.374 (.36)	.392 (.42)
15	-	-	-	.332 (.30)	.390 (.36)	.430 (.42)	.450 (.48)
16	-	-	-	.383 (.34)	.451 (.40)	.491 (.47)	.565 (.54)

Cary, Austin. 1939. Woodsman's Manual. The Harvard University Press.

Table produced on Harvard Forest. Worked out for red maple but holds for other species. Wood used for fuel down to a diameter of 2 inches.

Volume Table No. 4. Jack Pine in cords.
(Cords by the summation method in parenthesis.)

Diameter breast high (inches)	Total height of tree - Feet					
	40	50	60	70	80	90
	Volume in cords					
5	.03 (.03)	.04 (.03)	.04 (.04)	-	-	-
6	.04 (.04)	.05 (.05)	.06 (.06)	-	-	-
7	.05 (.05)	.06 (.07)	.08 (.08)	.09 (.09)	-	-
8	.07 (.07)	.08 (.09)	.10 (.10)	.12 (.12)	-	-
9	.08 (.09)	.10 (.11)	.12 (.13)	.14 (.15)	.16 (.18)	-
10	-	.12 (.13)	.15 (.16)	.17 (.19)	.20 (.22)	-
11	-	.14 (.16)	.17 (.19)	.21 (.23)	.23 (.26)	.27 (.29)
12	-	-	.21 (.23)	.24 (.27)	.27 (.31)	.31 (.35)
13	-	-	.24 (.27)	.28 (.31)	.32 (.36)	.36 (.40)
14	-	-	.28 (.31)	.32 (.36)	.37 (.42)	.41 (.47)
15	-	-	.31 (.36)	.36 (.42)	.41 (.48)	.47 (.54)
16	-	-	.35 (.40)	.41 (.47)	.47 (.54)	.53 (.61)

Cary, Austin. 1939. Woodsman's Manual. The Harvard University Press.

Volume of stems, bark on, between stump one foot high and three inches top diameter. (From the Lake States Forest Experiment Station.)

Volume Table No. 5. Merchantable volume in standard cords outside bark for individual trees, Pinus virginiana. (Cords by summation method in parenthesis.)

DBH	Total Height - Feet 20	30	40	50	60	70	80	90	No. of Trees
4	.008	.013	.020	.027	.031	-	-	-	2
	(.01)	(.01)	(.02)	(.02)	(.03)				
5	.012	.019	.027	.037	.044	-	-	-	19
	(.01)	(.02)	(.03)	(.03)	(.04)				
6	.021	.031	.043	.054	.064	.074	-	-	31
	(.02)	(.03)	(.04)	(.05)	(.06)	(.07)			
7	-	.040	.054	.068	.084	.100	.114	-	48
		(.04)	(.05)	(.07)	(.08)	(.09)	(.11)		
8	-	.056	.074	.091	.109	.127	.144	.162	55
		(.05)	(.07)	(.09)	(.10)	(.12)	(.14)	(.16)	
9	-	.071	.093	.115	.138	.161	.184	.205	97
		(.07)	(.09)	(.11)	(.13)	(.15)	(.18)	(.20)	
10	-	.083	.113	.140	.170	.197	.225	.254	95
		(.08)	(.11)	(.13)	(.16)	(.19)	(.22)	(.24)	
11	-	-	.135	.171	.204	.240	.272	.307	84
			(.13)	(.16)	(.19)	(.23)	(.26)	(.29)	
12	-	-	.158	.198	.241	.280	.321	.360	63
			(.15)	(.19)	(.23)	(.27)	(31)	(.35)	
13	-	-	-	.237	.281	.333	.378	.425	55
				(.22)	(.27)	(.31)	(.36)	(.40)	
14	-	-	-	.275	.333	.386	.441	.496	42
				(.26)	(.31)	(.36)	(.42)	(.47)	
15	-	-	-	.312	.374	.437	.498	.562	18
				(.30)	(.36)	(.42)	(.48)	(.54)	
16	-	-	-	-	.428	.498	.568	.640	8
					(.40)	(.47)	(.54)	(.61)	
17	-	-	-	-	.477	.555	.635	.711	2
					(.46)	(.53)	(.61)	(.68)	
18	-	-	-	-	.535	.625	.714	.802	3
					(.51)	(.59)	(.68)	(.76)	
Trees		11	37	53	89	201	231		622

Slocum, G.K. and W.D. Miller. 1953. Virginia Pine. North Carolina Agricultural Experiment Station Tech. Bull. No. 100.

It should be pointed out that the volume tables selected to illustrate the summation method of calculating cordwood volumes were prepared by different workers in different areas and noted that there is a difference in the degree of utilization practices, and possibly other factors affecting yield. Nevertheless, the yields are quite close for the various species at each diameter and height class. The volumes calculated by summation are also quite close; however, the greatest difference is noted in Volume Table 3, New England hardwoods, which was prepared for fuelwood down to a minimum 2" diameter, and in Volume Table 4, Jack Pine, which was cut to a stump height of 1 foot. Probably the actual cordwood produced from New England hardwoods and Jack Pine would have been closer to the volume calculated by summation if the utilization practiced had been more nearly like that practiced in pulpwood operations today.

The volumes calculated by summation appear to be sufficinetly accurate to justify their use in rough field approximations of the cordwood contents of individual trees and groups of trees, since the estimator does not have to refer to published statistics or basal area tables to arrive at his approximation, nor is it necessary to fell the tree to obtain the data needed for the calculation of volumes.

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FORESTRY IN THE PHILIPPINES

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Tropical rain forests, typical of Southeast Asia, occupy approximately 50% of the total area of the Philippines, and although their extent is being rapidly reduced as a result of logging and clearing for agriculture they are considered to be the most valuable renewable resource of the country. Extensive tracts of virgin forest are still to be found on the island of Mindanao and in Northern Luzon. Also, the island of Palawan is still richly forested, waiting to be developed and utilized.

Forest Types

Most important in the Philippines, whether judged according to area, volume or commercial importance is the dipterocarp type. It occupies about 2/3 of the forest area. Members of the dipterocarp family predominate, usually constituting about 75% of the volume of the stand. The type occurs in all parts of the Philippines and from sea level to a considerable elevation.

About 70% of the annual production of lumber for the country is provided by seven species of the dipterocarp group. These are:

White Lauan	(*Pentacme contorta* Vid.)
Red Lauan	(*Shorea negrosensis* Foxw.)
Apitong	(*Dipterocarpus grandiflorus* Blco.)
Yakal	(*Shorea gisok* Foxw.)
Tangile	(*Shorea polysperma* Merr.)
Manggachapui	(*Hopea acuminata* Merr.)
Guijo	(*Shorea guiso* Blco.)

Other extensive but less important timber types are:

Molave type - Occurs where there is a distinct wet and dry season. Stands are much more open then in the diptocarp type, and volumes are much lower.

Pine type - Found in the high altitude regions of Northern Luzon. The principal species is Benguet Pine (*Pinus insularis* Indl.). Pure stands are typical. Smaller areas of pine type, in which the type species is Tapulao (*Pinus merkusii* Jungh.), are found in Western Luzon and Mindoro.

Mangrove type - Occurring at the mouths of streams and on the shores of sheltered bays.
Beach type - Occupying sandy soil above the tide line.
Mid-mountain and Mossy type - The most important protection type, and is limited to high elevations.

Dipterocarp Type

The trees are truly magnificent, larger than hardwood trees have any right to be. They are straight, clean, and of high quality. Density of stands if often quite high, sometimes exceeding 130,000 bd. ft. per hectare (approximately 50,000 bd. ft. per acre). Some of the trees exceed 60 inches in diameter and 140 feet tall, with clear lengths up to 80 feet. The ages of the trees are not known because they do not have annual rings, but estimates seldom exceed 200 years even for the largest.

The virgin stands are complex; often 50 tree species or more are arranged in complex mixtures on a small area. A tally of a one hectare plot showed 66 species ranging in diameter from 30 to 160 cm (18 to 63 inches) dbh. The stands are many-aged. Undergrowth is usually dense.

In many ways the type is silviculturally simple to manage. Reproduction is usually present in the undisturbed forest, and response following logging is rapid if it is not destroyed. Small openings are soon filled by new reproduction. Light cuttings result in reproduction of many of the species found in the original stand. Heavy cutting will probably introduce intolerant, fast growing, but temporary species. It is thus possible to influence the species of reproduction considerably by the nature of the cutting.

It is sometimes stated that the rain forest cannot be destroyed by logging, no matter how destructive the logging may be. As long as the area is permitted to recover after logging, so that reproduction can be established and develop, the forest will restock quite quickly. The species composition may be considerably changed, there may be a dense vine stage, the appearance of high quality timber species may be delayed many years. If the area is not burned by "squatters," however, the species making up the original stand will usually overcome the less tolerant temporary species which invade following heavy cutting, and take over the stand. Apparently, this process is much more rapid in the tropics than in the temperate zone.

Typically, several large culls per hectare (2.471 acres) and much debris are left after logging. Where economic clear cutting is practiced, a badly decimated stand is left, with most residuals either unmerchantable due to defect or size. Many good quality trees are damaged during logging. Damage is excessive according to United States' standards and utilization standards are low. Trees less than 26 inches dbh are often considered unmerchantable and logs are commonly taken only to approximately 20 inches in the top, even in straight clean trees of good species. The stumpage prices are set by the Bureau of Forestry and are low per unit of volume.

The larger logging operators use modern equipment and methods. Highlead, or arch and tractor skidding is common and logs over 40 feet long with a 30 inch top diameter are frequently cut. The roads of the more successful loggers are built to high standards, surfaced, and well

maintained. Small and poorly financed operators in the Philippines, as in other parts of the world, often build poor roads, have poor equipment and do a poor job of logging.

Selective Logging

Approximately $98\frac{1}{2}\%$ of the forested land in the Philippines is owned by the government and administered by the Bureau of Forestry. Almost all commercial logging is therefore located on government land and subject to the regulations of the Bureau. In much the same way as in the United States government employees scale the timber, inspect the sale areas, and collect payment for the stumpage. A company is assigned to a particular concession area for periods of 10 years or more and the allowable annual cut is established by the government. Some of the concessions are quite large, exceeding 100,000 hectares (247,100 acres), with sufficient timber to provide sustained yields for large operations. Cutting is regulated to proceed at a rate calculated to permit regrowth before the second cut, and a community of interest is recognized between concessionaires and the Bureau of Forestry. Most of the larger companies are interested in retaining their concessions for an indefinite period. Consequently most of them try to abide by the Bureau's stipulations and regulations.

Selective logging is advocated for virgin dipterocarp forests, and standards for trees to be left are prescribed by the Bureau of Forestry. Sampling checks are made before cutting, and 60% of the sound and vigorous dipterocarps and other commercial species commonly sawn between 30 to 70 cm (18 to 28 inches) dbh, are selected to be left as residual trees. These trees are then marked by painting identification numbers on them, and their dbh, merchantable height in log lengths (one log length is 5 meters or 16.4 feet), and total height is recorded. Trees to be cut are marked with an arrow painted on the side toward the direction of fall. After logging, a tally of the residual stand is made by the Bureau of Forestry to determine if the number of satisfactory trees left is adequate. Trees marked as residuals, which qualify according to established standards are recorded; those injured during the logging process are likewise recorded, their volume calculated, and for those trees the operator is charged the regular stumpage price plus 100% penalty.

Selective logging was started under supervision of the Bureau in 1953, and each year the number of concessions under this regulation is increased. Initially, considerable resistance was experienced to the restrictions imposed; however, the larger and more progressive operators now accept and support the method. Smaller operators sometimes resist enforcement of the regulations. The general observation is that the small operator has less concern for the future and is less cooperative in leaving merchantable trees for possible future yield.

Considerable areas of forest are still being cut each year under little if any enforcement of selective logging. In some instances the operations have been in progress for many years, and thus date back to the period before the initiation of regulations. Certain other operators, working on small concessions, or operators logging areas which are already classified as agricultural lands, are not required to follow the selection system.

Export of Logs

Most of the best quality logs are exported. In 1957, logs and other wood products exported from the Islands provided international exchange totalling approximately $50,000,000. The export market accelerates the rate of cutting and more timber is being cut than domestic markets can absorb. Veneer logs, sold to Japan, are frequently made into plywood and shipped to the United States where they provide competition with plywood made in the Philippines. Some of the Philippine plywood is not as good quality as the Japanese product, so the market for the Philippine product is sometimes reduced due to competition with plywood made from its own raw material. There have been attempts to restrict the export of high quality logs and these efforts will probably be continued in the future.

Land Use

In undeveloped parts of the Philippines, as in many tropical countries, local people frequently practice "shifting agriculture." Much of the soil of areas still forested is not inherently fertile, although magnificent forests develop if they are left without disturbance for a long time. The nutrients necessary to nourish the trees are accumulated by the forest itself and are used over and over again. The forest develops soil tilth under the protection provided by the canopy; the dropping of leaves, decay of wood material, spreading and penetration of roots, and the work of associated soil fauna and flora. When the forest is removed and agricultural crops are planted, good yields are produced for a few years. However, high temperatures and heavy rains usually cause rapid oxidation and leaching and, where the slope is steep, erosion occurs. The physical structure of the soil deteriorates, the supply of nutrients is reduced, and the yield of the planted crops is less. The weeds and grasses that invade this type of soil compete for the nutrients that are present. Much of the area cleared of forest eventually becomes greatly reduced in productivity, and eventually it is abandoned. Then the farmer moves on and clears a new area. Clearing of land for agriculture usually follows logging, so large areas are sometimes opened up more or less as units as people move in to farm the land.

The population of the Philippines is growing rapidly; consequently the pressure for agricultural land is very great. In many parts of the Islands, people are so determined to obtain land for agricultural use that the local law enforcement agencies are unable to control them adequately. A forest land classification system has been developed to determine whether forest land should remain in forest or be released for agriculture. Often land classified for permanent forest and selectively logged, leaving good residuals, is invaded by people. The timber is cleared, usually without commercial utilization of it, and agricultural crops are planted, although the people occupying the land ("squatters") are illegally in possession. Eventually they may obtain title to the land, because after the forest has been destroyed it appears useless to insist that it is still "forest land." It is estimated that each year between 30,000 and 60,000 hectares (74,000 and 148,000 acres) of forest land are cleared illegally by squatters with little or no return from the timber. Accurate data are not available.

Unfortunately, much of this land does not stay in agriculture, because

it proves to be unproductive under the agricultural practices used, and is abandoned. In this process the forest is destroyed, the farmer is able to maintain himself only with great effort and at a submarginal level, and relatively unproductive grass and brush typically becomes the vegetation. Out of a total area of 29,000,000 hectares (71,500,000 acres) for the Islands, there are now over 5,500,000 hectares (13,600,000 acres) of grass and brush, or a total of more than half as great as the area of commercial forest. (App. 9,000,000 hectares or 22,200,000 acres.) Frequent fires maintain the grass and brush cover. Eventually much of this area will require reforesting. This will be a slow and expensive process.

Reforestation

There are at present approximately 60 reforestation projects in the Philippines. In 1958, some 9,000 hectares (22,200 acres) were reforested by direct seeding or by planting. If all this area is successfully stocked, it would be less than a third of the area of forest land estimated to be denuded during the year. Frequent fires are a hazard to planted and recently seeded areas, so that some of the area planted each year is lost.

Protection

Much has been stated above which pertains to forest protection. Additional comments regarding fires are appropriate. Throughout the Islands there seems to be little concern about fire. In many areas and during much of the year the forest is not inflammable. However, in most parts of the Islands there is a more or less distinct dry period. Thus, during part of the year or during dry years, conditions develop where fire will run over the forest floor. Underbrush, cut and allowed to dry during this period, will burn hotly and kill older trees. Much of the forest land clearing is done at these times. Fires frequently escape from areas being cleared by fire. There is little evident concern as long as houses are not endangered. Few efforts are made to suppress fire in the forest even though the area is forest land supporting valuable timber. Almost all fires in the forest are set on purpose to assist in clearing or preparing land for crops. The practice has been followed so long that persuading people that they must keep fire strictly confined to the area currently being cleared will be difficult.

In the Mountain Province of Luzon there is a large area of pine. Here, there is a pronounced dry period in April and May, and fires are frequently allowed to escape into the forest where they destroy reproduction and larger trees. A fire may be used to assist in clearing a small area at the bottom of a mountainous slope, then permitted to escape and burn to the top of the ridge. Although the pine is fire resistant except as reproduction, repeated fires have caused widespread deterioration of the forest cover, and erosion is much in evidence. Burning by hunters and by people going from one place to another after dark is common. In one instance the writer found a fire of several hectares burning briskly beside a well-travelled mountain road. There was no evidence of efforts to suppress it and no one showed interest, even though a considerable area of young pine was being burned. There is very little organized fire prevention, presuppression, or suppression work done in the Mountain Province.

The extensive areas of grass and brush burn frequently. On steep land such fires are probably impossible to suppress after they have once started. Planted trees and natural reproduction is destroyed, the grass sod is thinned, and erosion damage is evident in many places. The frequent fires prevent displacement of the coarse grass by other vegetation. The grass, however, is not very valuable as forage.

Almost all of the Philippines were originally forested. The 5,500,000 hectares (13, 600, 000 acres) now in grass and brush thus represent the cumulative effect of clearing forest from land, using it for agriculture, and then abandoning it. The conversion from high quality forest to poor grass is still progressing as a result of the clearing of land which should remain in forest. It appears that the change is a permanent one under present conditions.

The Future

Although problems relating to the forest resource are serious, there are now many indications that Philippine foresters are gaining in their efforts to develop corrective programs. Government officials, lumbermen, and public leaders are in agreement that a greater effort to protect the forest resource, and to initiate conservative and long time management practices is essential, if quality wood is to continue to be available for industry, and if the watershed and other associated forest services are to be maintained and increased. The National Economic Council of the Philippine government is supporting a broad forestry program for the country. The International Cooperation Administration is contributing to the development of the Bureau of Forestry Program, and Forest Products Research Institute, and the College of Forestry. Greater numbers of professionally trained foresters are urgently needed and the College of Forestry of the University of the Philippines is receiving assistance to expand its facilities to train them. The development of a public program of improved land use, with emphasis on forests, can be observed. It is none too soon.

Summary

The dipterocarp forests of the Philippines are magnificent. However, as has been the case in many other countries having an abundance of high quality forest but undeveloped industry, wood is cheap compared to labor and forests appear to be little valued by the people. Cutting, land clearing, and fire are reducing the forest area more rapidly than is prudent. Repeated burning of grass and brush areas prevents natural reproduction of forest and destroys plantations. Cutting methods are improving and increased attention is being given to conservation; however, much work and a considerable time will undoubtedly be required for marked improvement.

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AN ANALYTICAL APPROACH TO THE MANAGEMENT OF FOREST LAND FOR BEEF CATTLE AND TIMBER PRODUCTION

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The multiple-use concept has been advocated and practiced by our federal forestry agencies for half a century. It is generally felt that timber production is not the sole function of our forest lands. Forest, water, wildlife, grazing and recreation are considered in all management decisions. The universal acceptance of this concept presents two major problems: (1) Is multiple-use always feasible on forest lands? (2) If multiple-use is tenable on a given area, what is the optimum combination of uses for maximizing the net value product? An analytical approach which may aid in the answering of these questions for two uses on a specific forest area is presented in this paper.

In the establishment of an optimum combination norm for beef cattle and timber production in the Longleaf-Slash Pine forest type of Southeastern United States, the author has evaluated existing data through the principle of the marginal rate of substitution. A rather detailed description of the transformation of basic physical data to usable economic information is presented. A lack of complete physical, revenue and cost data at several intensities of cultural treatments necessitates a shift from a practical to a theoretical situation before the paper is logically concluded.

Description of the Longleaf-Slash Pine Forest Type and Its Associated Wiregrass Range Type

This forest and range is located on the Coastal Plain of Southeastern United States. It is situated generally along the Gulf Coast from southeast Texas to Florida and along the Atlantic Coast from Florida to localized areas in central North Carolina.

The climate is descriptively termed mild and humid. The total annual precipitation is approximately 50 inches, equally distributed throughout the year. The mean annual temperature is approximately 68°F, and the growing season is 7 to 8 months long (Westveld 1949).

The topography of the area bears a strong resemblance to the Continental Shelf. It is a gently rolling plain in its infancy of the erosion cycle. With increasing distance from the coast, tributary streams increase in number and size, and the elevation increases from 0 to 500 feet (Fenneman 1938). The primary great soil groups are the Red and Yellow Podzolics and the Ground Water Podzols (Lutz and Chandler 1947).

The Longleaf-Slash Pine forest type is a subclimax community located on flatwood ridges, old fields and pond borders which are intermittently wet. If normal ecologic succession were effected, this type would give way to an inferior Bottomland Oak type. Cutting and cultural practices of men maintain a coniferous forest community at various quality levels (Society of American Foresters 1954). The associated Wiregrass range type consists of pineland threeawn (Aristida stricta Michx.), curtiss dropseed (Sporobolus curtissii Vasey), bluestems (Andropogon spp. L.), carpetgrass (Axonopus affinis Chase), panicums (Panicum spp. L.), and paspalums (Paspalum spp. L.). With the exception of two or three months during the spring, wiregrass herbage is generally deficient in protein, phosphorus and calcium. Prescribed winter burning is a common practice to increase availability, palatability, and nutritive value of the herbage during late winter and early spring (Williams et al. 1955).

The Longleaf-Slash Pine forest type contributes a major portion of the 19% of the U. S. lumber and 32% of the U. S. pulpwood production furnished by the states of Alabama, Florida, Georgia, Louisiana, and Mississippi (American Forest Products Industries 1954). The 24,000,000 acres of the Wiregrass range type which could support approximately 1,330,000 animal units* for a six-month grazing period is capable of producing 230,000,000 pounds of beef yearly (Campbell and Cassady 1951a).

Establishment of the Optimum Combination Norm

When resources are subjected to intensive dual purpose management, the two products are competing for the use of certain site factors. Output of one can be increased only by sacrificing output of the other. Any decision related to the selection of an optimum combination of these two products or of but one product, must be based on a choice indicator such as a pricing mechanism.

The basic physical information used to determine the optimum combination norm for beef and timber production on the Longleaf-Slash Pine area was obtained from Halls (1955). As seen in Figure 1, there is a decrease in the production of forage with an increase in forest stand density up to 148 square feet of basal area. Beyond this density, forage production remains constant at approximately 300 pounds of oven dry grass per acre. Within the basal area density of 5 to 148 square feet, the competition between forage and timber for light, soil moisture, and soil nutrients is positive. According to Hopkin (1954), a curve convex to the origin indicates that no combination of two uses is as productive as one alone. However, a lack of physical complementarism does not preclude the possibility of an increasing economic rate of substitution. Consequently, an evaluation of the application of costs and returns to physical data was instigated.

To make the economic comparison more tenable, forage production was converted to yearling steer gains per acre per year, and basal area to timber growth per acre per year. The former was effected as shown

*An animal unit is considered 1,000 lb. liveweight, or roughly equivalent to the weight of a cow and a calf.

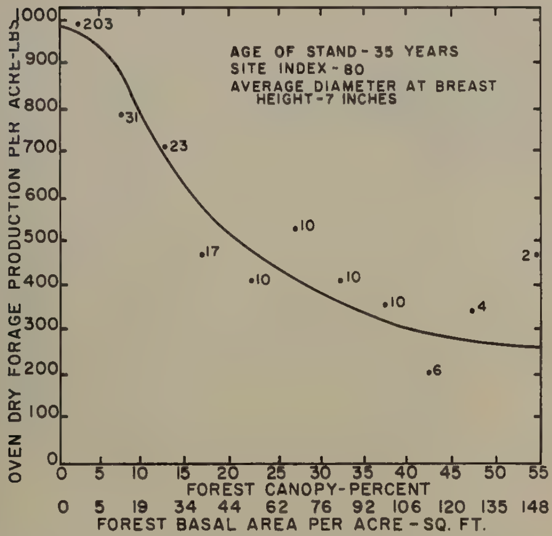

Figure 1. The relationship of Wiregrass range type forage production to Longleaf-Slash Pine stand density (Halls 1955).

in Table 1, the latter as shown in Table 2. The unit conversion of both variables is presented in Figure 2. The actual production possibilities curve plotted from the converted units is shown in Figure 3. It represents the relationship of timber growth and yearling steer gains per acre at one level of cultural practices. The construction of iso-cost curves, necessary to determine the desired norm, is possible only when several production possibilities curves at different levels of cultural practices are available. Unfortunately, the data necessary to construct these curves are not available at the present time. The lack of these data and sufficient information relevant to costs necessitates a shift from a practical to a theoretical situation at this point. In an attempt to emphasize the deficiency in these kinds of data, the author has developed a hypothetical situation based on the ideas of Hopkin (1954) and Gregory (1955).

In this example, the timber is grown under a sustained yield system of even-aged management. Each age class of a 70-year rotation is represented in even-aged blocks. An annual cut equal to the mean annual growth is made, and the timber sold as logs decked at the roadside. The yearling steers are bought in March, grazed on the range until October, and sold as feeders by an auctioneer at the forest.

With an increased intensity of cultural practices, the production possibilities curves are shifted upward and to the right as shown in Figure 3. Prior to the construction of the iso-cost curves, costs are assigned at systematic intervals along each of the production curves at several combinations of timber and yearling steer production. The iso-cost curves

Table 1. Summary of data used to convert forage production to beef gains per acre per year.

Oven dry forage production per acre[a] (pounds)	Forage required per acre per month[b] (pounds)	Grazing capacity per acre per month[c] (animal units)	Grazing capacity per acre per month[c] (yearling steers)	Grazing capacity per acre per year[d] (yearling steers)	Average yearling steer gains per year[e] (pounds)	Average yearling steer gains per acre per year[f] (pounds)
1000	1320	0.76	1.01	0.17	178	30
900	"	0.68	0.90	0.15	"	27
800	"	0.61	0.81	0.13	"	23
700	"	0.53	0.71	0.12	"	21
600	"	0.45	0.60	0.10	"	18
500	"	0.38	0.51	0.09	"	16
400	"	0.30	0.40	0.07	"	12
300	"	0.23	0.31	0.05	"	9
200	"	0.15	0.20	0.03	"	5
100	"	0.08	0.16	0.02	"	4

[a] Data from Halls (1955).

[b] Based on the forage weight method of inventory (Campbell and Cassady 1951b). 18 lbs. forage per animal unit per day + 26 lbs. left to insure proper use x 30 days per month = 1320 lbs. per acre per month.

[c] Conversion to grazing capacity.

$$\frac{\text{1000 lbs. forage produced per acre}}{\text{1320 lbs. forage required per acre per month}} = \text{0.76 animal units per acre per month.}$$

$$\frac{\text{0.76 animal units per acre per month}}{\text{0.75 animal units per yearling steer}} = \text{1.01 yearling steers per acre per month.}$$

[d] Normal length of grazing year considered to be from March to October.

[e] Average daily gains of yearling steers on Wiregrass range type from March to October - 1.12 lbs. (Campbell and Cassady 1951a).

[f] Average yearling steer gains per acre per year. 178 lbs. of yearling steer gains per year x 0.17 yearling steers per acre per year = 30 lbs. of yearling steer gains per acre per year.

Table 2. Summary of data used to convert basal area to average yearly growth per acre.

Basal area[a] (square feet)	Mean annual timber growth per acre[b] (board feet)
148	403
135	358
120	327
106	289
92	250
76	207
62	169
49	133
34	92
19	52
5	14

[a] Data from Halls (1955).
[b] Growth extrapolated from data of the U.S. Forest Service (1929).
Age of stand - 35 years.
Site index - 80 (average height of dominant trees at 50 years of age equals 80 feet).
Average basal area - 131 square feet per acre.
Mean growth - 357 board feet per acre per year.

are then plotted by connecting points of equal cost in the same manner as contours are plotted from known points of elevation on a topographic map (Figure 3). A series of hypothetical iso-cost curves which identify all product combinations produced at equal cost, is shown in Figure 4.

The iso-revenue curve also necessary to determine the desired norm, is established through a comparison of a return for a specified quantity of beef and the amount of timber necessary to obtain an equal return. For example:

Beef

Return - 20 cents per pound.

Return for a given quantity - 20 pounds x \$0.20 per pound = \$4.00.

Timber

Return - \$35 per thousand board feet.

Quantity necessary to give a \$4.00 return - $\frac{\$4.00}{\$.035 \text{ per board foot.}}$ = 114 board feet.

Equivalents

114 board feet of timber equals 20 pounds of beef.

5.7 board feet of timber equals 1 pound of beef.

The above values establish the iso-revenue curve shown as a negatively sloping line in the lower left-hand corner of Figure 4. Any combination of beef and timber production indicated by a point on this line represents

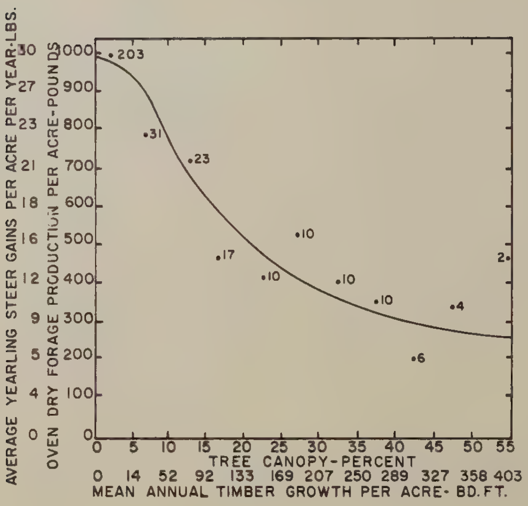

Figure 2. A production possibilities curve showing the relationship of yearling steer gains per acre per year to mean annual timber growth.

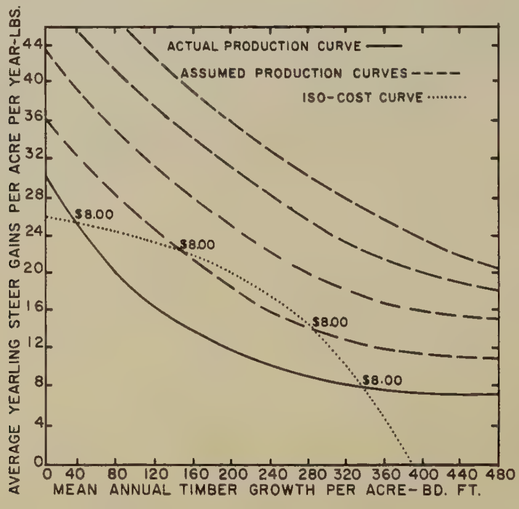

Figure 3. An actual and several assumed production possibilities curves from which many iso-cost curves, similar to the $8.00 cost curve, are constructed.

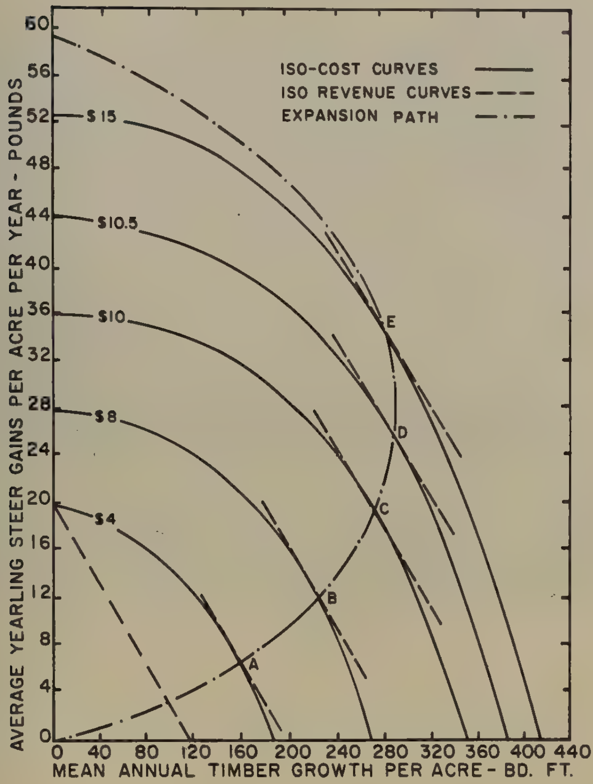

Figure 4. Hypothetical iso-cost, iso-revenue, and expansion curves which locate a series of beef and timber combinations leading to the establishment of a norm.

a total revenue of $4.00. As long as the ratio between beef and timber prices remains unchanged, any other level of revenue would be indicated by a curve parallel to the initial iso-revenue curve. Thus, a series of iso-revenue curves can be drawn as shown in Figure 4. These represent progressively higher levels of revenue as distance from the origin increases.

The highest revenue for a given cost of production is obtained where the iso-cost curve is tangent to an iso-revenue curve. The final step leading toward the optimum combination for maximizing the net value product begins with the construction of the expansion path, a line connecting points at which successive iso-cost curves are tangent to iso-revenue curves. The expansion path is shown in Figure 4.

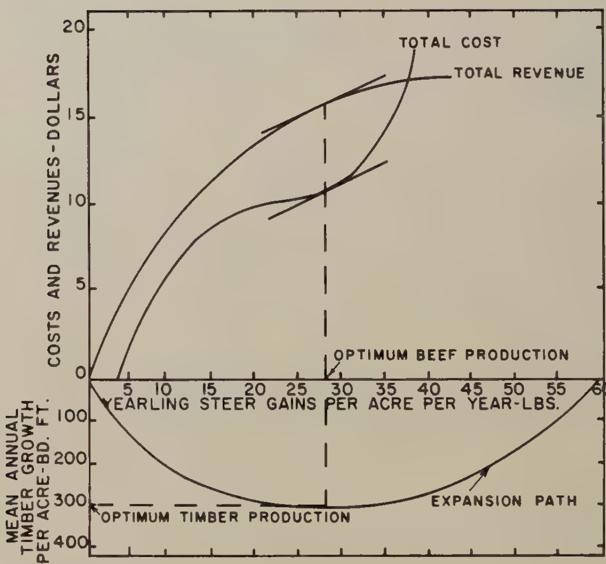

Figure 5. A hypothetical optimum combination for maximizing the net value product from beef cattle and timber production.

Once the expansion path is plotted, the combination on the path which maximizes net revenue is found. The solution is illustrated in Figure 5. The lower part of the diagram consists of the expansion path. The upper half represents the total cost and total revenue curves. The total revenue and cost curves are plotted from points A, B, C, D, and E along the expansion path. The values obtained are shown in Table 3.

Since the objective is to maximize the net value product, the optimum combination of timber and beef is located where the difference between total cost and total revenue is greatest (Gregory 1955). This difference is found where the slopes of the total cost and total revenue curves are equal (marginal cost equals marginal revenue). As seen in Figure 5, the hypothetical optimum combination occurs where 27.5 pounds of beef and 300 board feet of timber are produced per acre per year. Thus, a hypothetical norm is established for maximizing the net value product from beef cattle and timber production in the Longleaf-Slash Pine forest type of southeastern United States.

If the expansion path had paralleled either of the two axes, Hopkin's observation concerning the lack of complementarism, cited earlier in this paper, would then be valid for the economic as well as the physical

Table 3. The revenues and costs of timber and beef as taken from the expansion path in Figure 4.

Points of tangency	Revenues (dollars)	Costs (dollars)
A	6.96[a]	4.00
B	10.29	8.00
C	13.44	10.00
D	15.27	10.50
E	16.83	15.00

[a] Total revenue obtained as follows:

Timber	- 160 board feet x $.035 per board foot	= $5.60
Beef	- 6.8 pounds x $.20 per pound	= $1.36
	Total	$6.96

data. As a matter of fact, there is no reason to believe that the path shown in the hypothetical illustration is indicative of the real situation. There is an equal possibility that no combination of timber and beef production would be as productive as one alone.

Conclusions

The original intent of the author was to carry through to completion the application of the aforementioned economic principles to actual physical data. Unfortunately the intent "bogged down" because of a lack of information relevant to physical relationships, costs and returns at various levels of cultural practices. The introduction of hypothetical costs and returns, however, indicates that this technique does have possibilities in aiding planning agents in establishing the proper norms in the management of our federal forest and grazing resources. A serious deficiency arising at the present time is a lack of physical data showing the relationship between different products obtained from the same resource at various levels of cultural practices. Additionally, management of much of our forest resources has not been in effect long enough to insure some form of sustained yield as advocated in this paper. Finally, the author suggests that any future research pertaining to this problem should definitely include all costs and revenues, with corresponding inputs and outputs in physical terms, as a necessary adjunct to the physical data.

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TREE VOLUME AND REALIZATION VALUE DETERMINATION FROM CRUISE DATA BY ELECTRONIC COMPUTER IN OREGON BY THE UNITED STATES DEPARTMENT OF THE INTERIOR, BUREAU OF LAND MANAGEMENT

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The Bureau of Land Management of the United States Department of the Interior administers approximately $2\frac{1}{2}$ million acres of high-valued timberland in the State of Oregon. This $2\frac{1}{2}$ million acres may be roughly categorized into 2 million acres of O & C revested lands and $\frac{1}{2}$ million acres of public domain lands. Because of the checkerboard pattern of the O & C lands intermingled with private lands that have been logged rather intensively and the fact thet the O & C lands support some of the finest old growth Douglas-fir (Pseudotsuga menziesii) timber found in the world, the responsibility for assessing the volumes and the values of this timber for public sale rests heavily on the shoulders of the Bureau foresters.

The Bureau has long recognized that the sale of timber on the basis of standing tree cruise represented the best method of disposal for the conditions existent in the State of Oregon. The advertisement for each individual sale tract gives the estimated volume derived by cruise and the minimum bid price which will be accepted in competitive bid for the tract. The bidder in effect states the price he will pay for all timber on a specified tract. While no guarantee is made of the volume on that tract and technically the minimum total appraised price is the critical factor in the sale, the bidders, particularly the smaller operators, were found to rely heavily on the cruise as an index of value in their bidding.

To insure the optimum degree of accuracy in the derivation of volume and values, four important factors were isolated for study and development:

1. It was found the forester assigned to do the cruising had to have an inherent ability and a strong desire for this exacting type of work.
2. It was necessary to develop accurate volume tables to bridge all the conditions of timber found within and between species.
3. It was necessary to develop log grading rules that would accurately reflect end product values.
4. It was necessary to develop an electronic program that could accurately break the forester's cruise data down into a large number of volume and value items needed by the Bureau and by prospective purchasers. In other words, the value of the standing timber had to be assessed as well as a reliable estimation made of the end products and values that could be produced from this particular stand of timber.

The resolution of the problem was undertaken in the order just given. It was found that not all graduate foresters were good cruisers. Some lacked the natural judgment, the ability to ocularly estimate heights and diameters of standing trees or they were handicapped by inability to consistently differentiate many of the external characteristics so important in the evaluation of tree log grades. Other foresters, possessing the peculiar abilities to develop into good timber cruisers, lacked the desire to specialize in this exacting and responsible field. All remaining foresters were carefully screened and the best were selected as cruising specialists under the new system. These men were provided with intensive training on actual timber sales under the supervision of skilled timber cruisers who had spent many years at this work. In addition they were trained in log scaling to permit them to recheck their own cruising work. The cruisers were also required to periodically visit sawmills operating on materials taken from their particular areas of responsibility to watch the breakdown of problem logs. Each of these men was called in twice a year to take part in timber cruising and scaling schools. This intensive program of training was found to pay off handsomely. With this approach one of the important restrictive variables was controlled.

The Bureau had over the years developed and used many types of volume tables. Some were limited to a given species, others covered a species within one locality. Despite rather wide acceptance of many of these tables, they were found, after testing, to be lacking and though reasonably accurate over large areas, failed to provide the accuracy required for specific tracts. It was found that Bruce and Girard's form class tables for the 16-foot log proved the best for the Bureau's conditions of species and needs. Not only do these tables possess the necessary accuracy and flexibility, but two formulas had been developed by Bruce and Girard providing a practical method for the translation of basic cruise data by electronic data processing.

These two formulas are used for determining the scaling diameters of any given log in the tree and then computing the actual board foot volume by formula of the given log. In other words it was possible, through the use of these formulas, to segregate the scaling diameter and the volume of any log in a tree. The two formulas were:

1. $D = \dfrac{L}{0.9L + 1.1} + 0.5$ for 16-foot logs (after Behre's hyperbola).

D represents the diameter inside bark at any specified point on the tree above the first log up to the merchantable top (where $D = 0.5$) and is expressed as a decimal fraction of the diameter inside bark at the top of the first log.

L represents the distance from the merchantable top (where $D = 0.5$) down to any specified point on the tree where D is required and is expressed as a decimal fraction of the distance between the merchantable top ($D = 0.5$) and the top of the first log ($D = 1.0$).

For example, a five log tree would have:

	D value top of log	L value top of log
Fifth log	0.500	0/4 = 0
Fourth log	0.689	1/4 = 0.25
Third log	0.823	2/4 = 0.50
Second log	0.923	3/4 = 0.75
Butt log	1.000	4/4 = 1.0

2. $V = 0.79D^2 - 2D - 4$

D is the scaling diameter (in inches) of a given log. Volume is in board feet (Scribner).

The one limiting factor in the successful application of these tables was a need for a reasonably accurate and fast method of deriving form class in the field. After this hurdle was successfully overcome, the Bureau computed a complete volume table based on the form class principle. The volume tables were set up in the form of taper tables and they bridged a form class range of 66 to 94 inclusive, a tree diameter breast height range of 12 inches through 106 inches and a range in numbers of 16-foot logs from 1 through 16. For a tree with any given form class, dbh, and number of logs in height, it was possible to obtain the scaling diameter for each of the component logs, the volume represented by that particular log and the cumulative volumes up to that point within the tree (Fig. 1). This taper feature was necessary in order to dovetail the volumes and log diameters with the log grading rules.

The third big factor in the development of a new system for accurate derivation of volumes and values was the crystallization of log grading rules that reflected external characteristics suitable for cruising standing trees. In Oregon most of the log grading systems are principally judgment systems tailored for grading logs where both cross sections are visible. The cruiser was forced to judge whether a given log in a standing tree could "cut-out" a specified, but often arbitrary, amount of various end products while being denied a chance to see the ends of the "log." In order to provide the cruisers with a standard basis for value estimation, it was necessary to develop what could be termed an arbitrary grading system. Existing judgment rules were modified and reworked in light of findings from mill product recovery studies (the results of which were to be used for grade breakdown and thus value determinations) that were conducted in cooperation with the United States Forest Service, Bureau of Indian Affairs and the Pacific Northwest Forest and Range Experiment Station. As an initial measure, all judgment factors that could be eliminated were discarded. To reduce misunderstanding and misinterpretation, all log grades were diagramed to show the important external characteristics. In this manner the two major species, Douglas-fir and ponderosa pine (*Pinus ponderosa*), were diagramed and described (Figs. 2 and 3). By using these diagrams no two cruisers are likely to vary to any degree in their grading accuracy. The timber sale purchasers welcomed this portrayal of log grades because it permitted them to reconcile the Bureau grades with their own individual mill grades.

Line 1 - Diameter top log
Line 2 - Volume per log
Line 3 - Cumulative volume

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
Oregon State Office

FORM CLASS 78

Scribner Decimal C.
16-foot logs

DBH	Height	Log Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total Vol. in Tens
60	4	47	42	35	23													
		166	134	88	38													
		166	300	388	426													426
	5	47	43	38	32	23												
		166	140	107	74	38												
		166	306	413	487	525												525
	6	47	44	41	36	31	23											
		166	148	127	92	71	38											
		166	314	441	533	604	642											642
	7	47	44	42	38	35	29	23										
		166	148	134	107	88	61	38										
		166	314	448	555	643	704	742										742
	8	47	45	43	40	37	33	29	23									
		166	152	140	120	103	78	61	38									
		166	318	458	578	681	759	820	858									858
	9	47	45	43	41	38	36	32	28	23								
		166	152	140	127	107	92	74	58	38								
		166	318	458	585	692	784	858	916	954								954
	10	47	45	44	42	40	37	35	31	28	23							
		166	152	148	134	120	103	88	71	58	38							
		166	318	466	600	720	823	911	982	1040	1078							1078
	11	47	45	44	43	41	38	36	34	31	27	23						
		166	152	148	140	127	107	92	80	71	55	38						
		166	318	466	606	733	840	932	1012	1083	1138	1176						1176
	12	47	46	44	43	41	39	37	35	33	30	27	23					
		166	159	148	140	127	112	103	88	78	66	55	38					
		166	325	473	613	740	852	955	1043	1121	1187	1242	1280					1280
	13	47	46	44	43	42	40	38	37	35	32	29	27	23				
		166	159	148	140	134	120	107	103	88	74	61	55	38				
		166	325	473	613	747	867	974	1077	1165	1239	1300	1355	1393				1393
	14	47	46	45	44	42	41	39	37	36	34	32	29	27	23			
		166	159	152	148	134	127	112	103	92	80	74	61	55	38			
		166	325	477	625	759	886	998	1101	1193	1273	1347	1408	1463	1501			1501
62	4	48	43	36	24													
		173	140	92	40													
		173	313	405	445													445
	5	48	45	40	33	24												
		173	152	120	78	40												
		173	325	445	523	563												563
	6	48	45	42	37	32	24											
		173	152	134	103	74	40											
		173	325	459	562	636	676											676
	7	48	46	43	40	36	30	24										
		173	159	140	120	92	66	40										
		173	332	472	592	684	750	790										790
	8	48	46	44	41	38	34	30	24									
		173	159	148	127	107	80	66	40									
		173	332	480	607	714	794	860	900									900
	9	48	46	45	43	40	37	33	29	24								
		173	159	152	140	120	103	78	61	40								
		173	332	484	624	744	847	925	986	1026								1026
	10	48	47	45	43	41	39	36	32	29	24							
		173	166	152	140	127	112	92	74	61	40							
		173	339	491	631	758	870	962	1036	1097	1137							1137
	11	48	47	45	44	42	40	37	35	32	28	24						
		173	166	152	148	134	120	103	88	74	58	40						
		173	339	491	639	773	893	996	1084	1158	1216	1256						1256
	12	48	47	46	45	43	41	39	36	34	31	28	24					
		173	166	159	152	140	127	112	92	80	71	58	40					
		173	339	498	650	790	917	1029	1121	1201	1272	1330	1370					1370
	13	48	47	46	45	43	42	40	38	36	33	30	28	24				
		173	166	159	152	140	134	120	107	92	78	66	58	40				
		173	339	498	650	790	924	1044	1151	1243	1321	1387	1445	1485				1485

Figure 1. Excerpt from Bureau of Land Management Taper and Board Foot Volume Tables.

NO. 2 SAWMILL

32' - 24" Log

Many small live knots up to 2-1/2" in diameter. This type of No. 2 Sawmill log may be found in any log 12" and over but usually occurs in logs in the lower diameter range.

Figure 2. External characteristics of No. 2 Douglas-fir Sawmill log. Excerpt from Bureau of Land Management Douglas-fir Log Grading Handbook.

NO. 2 SAWMILL		KEY
1. Chief requirement		Suitable for manufacture of lumber in the following grades: 1. Construction or Better (from small knotted logs) 2. Shop and Better (from large knotted, cluster or burl type of log)
2. Age of tree		Any
3. Surface clear requirement		None (except as cited in 6B below)
4. Position in tree		Any
5. Minimum measurements	A.	Diameter - 12"
	B.	Length - 16'
	C.	Merchantability - 33-1/3%
6. Knots permitted - Type 1	A.	Live, mostly 2-1/2" in diameter and smaller
Type 2	B.	Larger knots, clusters and burls. Permitted provided the clear areas between them total at least 70% of the entire surface area of the log. Clear areas must be at least six feet in length.
7. Slope of grain A. Must not exceed	A.	2-1/2" per foot on logs 12" to 20" 3" per foot on logs 21" to 35" 3-1/2" per foot on logs 36" to 50" 4" per foot on logs 51" and over
8. Log types (2)		1. Many limbs or knots - Construction lumber 2. Few, large limbs or knots - clusters or burls - Shop or short Clear lumber
9. Defects permitted		Any - provided the portion of the log free of the defects meets the above chief requirement

Figure 3. Description of No. 2 Douglas-fir Sawmill log. Excerpt from Bureau of Land Management Douglas-fir Log Grading Handbook.

Since the principal species, Douglas-fir, is normally used to produce not only lumber items but also veneer for the manufacture of plywood, the grading rules had to reflect these two widely divergent types of end products. Six mill studies to determine veneer recovery of peeler logs had been made in cooperation with the U.S. Forest Service, the Bureau of Indian Affairs and the Pacific Northwest Forest and Range Experiment Station. The results of these studies permitted a defining of the three peeler log grades. These log grades were then tied in with the average product recoveries determined from the six mill studies.

Since the Douglas-fir represented the more complex processing, all further discussion will be limited to that species. We found that little incidence of sawing peeler grade logs for lumber products existed. As a consequence it was unnecessary to develop sawmill log grade equivalents for the peeler log grades. The log grades now being used for Douglas-fir represent three peeler log grades and two sawmill grades. The peeler log grades were carried through the veneer items produced and then to

the equivalents in 3/8 inch plywood for the purposes of pricing. Each of the peeler log grades produced the four standard veneer grades, A, B, C and D. The sawmill log grades produced 12 items of lumber.

Determination of form class as well as log grading under many conditions can be extremely time consuming. In order to avoid losing, through excess time consumption, the advantages to be gained through more precise value and volume measurements, determination of grade and form class on a sample basis was a necessity. Random transect lines were run through various types of Douglas-fir stands having varying unit values per tree and varying timber form. Tree dbh, height in 16-foot logs, form class, and log grades were accurately determined and recorded. The data were analyzed by stands to determine, at the 5% level, the intensity of sampling necessary on average size sales to remain within value and volume limits of accuracy set by administrative decision.

In addition to considering the time consumption factor in cruising, that same factor had to be weighed in computing the cruise data. There too, use of excessive amounts of office time in working up volumes and values could more than offset increased gains of a more precise, though complex, system. Therefore, in order for the entire system to be effective, a computer program which could handle the computations with all the variables in the system, including that of sample grading, was essential. Fortunately, electronic computers have recently been perfected which, through a magnetic drum, magnetic tape, magnetic core, or other devices, possess sufficient data storage space to make the required program possible. The use of electronic data processing machines freed our skilled cruisers for more valuable utilization of their time in the field.

Each of the species to be processed was given a code number to indicate the program to be used in processing the data. Within species, each log grade, including cull logs, was given a code number for the purpose of selecting the processing instruction for each log. The cruise data for each species from the unit of area to be processed and printed in one output, were presented in two sections, one including the graded trees, and the other the ungraded trees, All trees were listed by dbh and height (number of 16-foot logs). In addition, all logs in the graded section were reported by log grade code. The form class, key to the taper determination base, was furnished for each tree. Normally, in Bureau work, suitability of timber to the use of a common average form class is one of the criteria for dividing the area cruised into units for processing. Consequently, in most cases one form class, the average, was submitted for use with all trees in a given unit or subsale (Fig. 4).

The first general step performed in the Douglas-fir program was the determination of the volume in graded trees. It was necessary to determine volumes by log grade for all logs, including culls. In addition, the volume of sawmill logs was segregated by one-inch diameter classes since a subsequent breakdown of volume into lumber grades was accomplished through use of a recovery table compiled in one-inch divisions.

The first phase of this step was to determine the d.i.b. at the top of the first 16-foot log for each tree. This was simplified to a considerable degree by grouping all trees of like dbh, height, and form class on one

Form No.-A1-87
July, 1959

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

TALLY SHEET

District Portland
District Sale No. P-25
Cruiser J Cruiser
T. 2N R. 14W Sec. 5 Sub. NE¼NE¼

Computer Sale No. X-111
Subsale No. 01
Species Douglas fir
Form Class 78
Sheet No. 1
Date 9-1-59

Graded - 01, Douglas-Fir, F.C. 78

DBH Logs	1	2	3	4	5	6	7	8	9	10	11	12	No. of Trees
16-2	5	6											1
24-7	5	-	-	-	6	-	-						1
36-5	3	-	5	-	6								1
40-8	1	2	3	-	5	-	-	-					1
56-9	7	-	3	-	5	-	6	-	7				1
													5

Ungraded, 01 Douglas Fir, F.C. 78

DBH Logs	1	2	3	4	5	6	7	8	9	10	11	12	No. of Trees
28-6													3
32-6													3
36-6													4
36-7													3
40-7	0	0											1
48-8													2
48-9													1
52-9	0							0	0				1
56-9													1
56-10										0			2
60-11	0									0	0		1
													42

Ungraded - 01, Douglas-Fir, F.C. 78

DBH Logs	No. of Trees
16-2	3
16-3	2
20-4	4
20-5	4
24-4	5
24-5	2

Totals: Graded - Lines 5 Trees 5 Ungraded - Lines 17 Trees 42

Figure 4. Bureau of Land Management Field Tally Sheet.

line of tally. Since form class is the ratio of the d.i.b. at the top of the first 16-foot log in the tree to the dbh of that tree, the important diameter was easily calculated by the simple multiplication of the dbh by the form class expressed as a decimal. Not only was this diameter used for determination of the volume of the butt log in the tree or trees in that category, but it was used to determine the diameter and hence the volume of each of the remaining logs in the tree or trees of that category. The diameters of the remaining logs were found by solution of the formula,

$D = \frac{L}{0.9L + 1.1} + 0.5$ mentioned earlier.

Since it was impractical to consistently refer to taper tables when grading a log in the field, there were occasional errors in grade where diameter limit was used as one of the limiting grading criteria. Thus each of the log grades was screened in the computer processing and any diameters found to be too small for that grade were dropped to the next lower grade accepting diameters of that size. Log volumes for each of the necessary divisions, i.e., log grade and diameter classes, were found in the Scribner Decimal C log rule. This is the standard for Bureau sales. However, analysis of many log volumes indicated that satisfactory volume determination accuracy for Bureau sales could be achieved through use of the formula $V = .79D^2 - 2D - 4$, an approximation of the Scribner rule discussed earlier.

Recovery tables used by the Bureau for product grade development have been published by the Pacific Northwest Forest and Range Experiment Station (Clarke et al., 1957; Matson, 1956). They include results of studies made by them in conjunction with other agencies.

The tables have been modified somewhat for Bureau use in order that they might be compatible with volume determination on a 16-foot log length basis. Total percentage of the recovered grades was converted to a 100% basis rather than using a particular log scale as 100%. Application of recovery table percentages to the volume in each log grade (and diameter class for sawmill logs) resulted in the log scale volume of each product grade in those divisions. These volumes were totaled by product grade. The lumber grade volumes were thus ready for price extension. However, an additional step was necessary to prepare peeler log recovery for price extension.

Since the volume of the final product, plywood, made from peeler logs is not measured in terms of board feet, but generally, as in the case of recovery studies used in this program, in terms of square feet of 3/8 inch plywood, it was necessary to use a conversion factor, known as a recovery ratio. The recovery ratios used in this program are those published by the Pacific Northwest Forest and Range Experiment Station (Clarke et al., 1957) for each peeler log grade and modified for 16-foot logs. The applicable recovery ratio was multiplied by the log scale volume of each veneer grade in each log grade to determine the volume of 3/8 inch plywood in square feet within each veneer grade. These square foot volumes were totaled by veneer grade and thus prepared for value extension.

The trees that were not graded were reported only by form class (usually the same average form class as the graded trees in the same

section), the dbh, and height. Only the cull logs were coded in this section but were assigned a different code than those in the graded trees to prevent any confusion. The volumes were determined in the same manner as those in the graded section. The merchantable volume was broken into log grades and product grades by giving them the same relative volumes found in the graded trees.

The total volume in each product grade (from graded and ungraded trees) was extended by the product unit price to determine total realization value in each product grade.

The output printed on the Bureau Timber Cruise Report lists for all trees, graded and ungraded, in addition to the identifying area and species codes, the total number of trees, number of merchantable logs, number of cull logs, cull volume, volume by log grade (which is coded), total merchantable volume, total gross volume and the number of board feet in the average log (Fig. 5). Some of these data were used in determination of logging costs, while others were statistics which had value in other Bureau analysis work and were solicited by prospective purchasers.

The log scale volumes were printed on the report for each product grade, which was coded. The volumes, in square feet of 3/8 inch plywood, in each veneer grade were also listed. Unit prices used and total extension value were printed for each product grade. Total log scale and value were listed for each type of log, peeler and sawmill, and for all logs.

The Timber Cruise Report was prepared so that the processing could be completed manually to derive the pond value per M b.f. for the timber by including the applicable defect and breakage factor and deducting the product manufacturing cost. Space was also arranged to determine the recovery percentage, a figure used in logging cost determinations.

The pond values were used subsequently to determine the appraised timber value by deducting logging and transportation costs and making an allowance for the operator's profit and risk.

A somewhat less complex program could have been used for a simple value determination were it not for the fact that it was desired to furnish all possible information, including products expected to be recovered, to prospective bidders. This program has proved very satisfactory for Bureau appraisal work.

A similar program, built for an individual plant recovery data, prices etc., could be of great value in industry operational planning. A recent publication by the Pacific Northwest Forest and Range Experiment Station (Gedney et al., 1959) may be of much help in developing data to use in such a program. Guides in sales planning, production, quality, plant scheduling, timber purchasing and in other areas could be realized.

SUMMARY

The pattern of ownership of Bureau of Land Management administered lands in Oregon and the high value of the timber thereon presented problems in the assessment of volumes and values of this timber for public sale. Sales of timber are made on the basis of a standing tree cruise.

BUREAU OF LAND MANAGEMENT

TIMBER CRUISE REPORT

DATE 3-1-59

SALE NUMBER	SUB-SALE NO.	SPE-CIES	NO. OF TREES	NO. OF MERCH. LOGS	1 VOL. MBF	2 VOL. MBF	3 VOL. MBF	4 VOL. MBF	5 VOL. MBF	6 VOL. MBF	CULL VOL. MBF	NO. OF CULL LOGS	TOTAL GROSS MERCH. VOL. MBF	TOTAL GROSS VOL. MBF	AVERAGE 16 FT. GROSS MERCH. LOG MBF
X 111	01	01	47	258	6.36	5.84	39.81		38.66	13.55	9.72	13	104.22	113.94	404

SUB-SALE	RECOVERED GRADES											
	A	B	C	D	E	F	G	H	I	J	K	L
LOG SCALE VOL. MBF	10.32	4.79	16.26	20.74	2.08	4.90	.21	13.55	14.59	8.44	6.77	1.56
3/8" PLYWOOD VOL. MSF	22.50	10.39	35.28	45.01								
3/8" PLYWOOD VALUE PER MSF	120.00	92.00	71.00	56.00								
LUMBER VALUE PER MBF					163.00	159.00	102.00	92.00	81.00	75.00	58.00	23.00
TOTAL VALUE	2,700.00	955.88	2,504.88	2,520.56	339.04	779.10	21.42	1,246.60	1,181.79	633.00	392.66	35.88

SUB-SALE	PEELER LOGS			SAWMILL LOGS		ALL LOGS	
	LOG SCALE MBF	3/8" PLYWOOD MSF	TOTAL VALUE	LOG SCALE MBF	TOTAL VALUE	LOG SCALE MBF	TOTAL VALUE
COMPUTOR TOTAL	52.11	113.18	8,681.32	52.10	4,629.49	104.21	13,310.81
CRUISE FACTOR	1	1	1	1	1	1	1
GROSS MERCHANTABLE	52.11	113.18	8,681.32	52.10	4,629.49	104.21	13,310.81
D & B CORRECTION	.95	.95	.95	.90	.90		
NET MERCHANTABLE	49.50	107.52	8,247.25	46.89	4,166.54	96.39	12,413.79

SALE	PEELER LOGS			SAWMILL LOGS		ALL LOGS	
	LOG SCALE MBF	3/8" PLYWOOD MSF	TOTAL VALUE	LOG SCALE MBF	TOTAL VALUE	LOG SCALE MBF	TOTAL VALUE
COMPUTED TOTAL (Check Only)	52.11	113.18	8,681.32	52.10	4,629.49	104.21	13,310.81
NET MERCHANTABLE	49.50	107.52	8,247.25	46.89	4,166.54	96.39	12,413.79

POND VALUE CALCULATIONS

PEELER LOGS

(TOTAL NET MERCH. VALUE) − (NET MERCH. VOL. MSF 3/8" PLYWOOD X MILLING COST PER MSF) / (NET MERCH. VOLUME MBF)

(8,247.25) − (107.52 X 36.63) / (49.50) = $ 87.05 POND VALUE PER MBF

RECOVERY

(NET MERCH. VOL. MBF) / (TOTAL GROSS VOL. MBF)

(96.39) / (113.94) = 84.6%

SAWMILL LOGS

(NET MERCH. VALUE) / (NET MERCH. VOL. MBF) = LUMBER REALIZATION − (MILLING COST PER MBF)

(4,166.54) / (46.89) = 88.86 − (26.99) = $ 61.87 POND VALUE PER MBF

ALL LOGS

(NET MERCH. PEELER VOL. MBF X PEELER POND VALUE PER MBF) + (NET MERCH. SAWMILL VOL. MBF X SAWMILL POND VALUE PER MBF) / (NET MERCH. VOL. MBF ALL LOGS)

(49.50 X 87.05) + (46.89 X 61.87) / (96.39) = $ 74.80 POND VALUE PER MBF

Figure 5. Bureau of Land Management Timber Cruise Report.

The problems were resolved in a four step program:

1. Graduate foresters were carefully screened and intensively trained in field techniques by qualified personnel.
2. Taper volume tables based on the Bruce and Girard form class concept were developed to serve all tree species and tree form variations found on Bureau lands in Oregon.
3. Log grades, based in external characteristics recognizable by a timber cruiser in the field, were developed for the two principal species, Douglas-fir and ponderosa pine. These log grades were designed from mill study data and were supported by product grade recoveries. Each log grade was clearly described and diagramed.
4. An electronic computing program, capable of converting raw timber cruise data into log grade and product grade volumes and realization values, satisfied the Bureau's fourth requisite.

Through the solution and application of the above mentioned points, it was possible to more accurately determine volumes and realization values for Bureau timber in Oregon, as well as provide much needed detailed data for the Bureau's statistical records and for prospective purchasers.

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MICHIGAN'S NATIONAL FORESTS

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U.S. Forest Service, Milwaukee, Wisconsin

Michigan has more national forest land than any other state east of the Rockies except one. The forests on this land have had a colorful past. They were once the magnificent woodlands of the American Indian. During the last century they were rapidly exploited by the white man, but more recently he has begun a slow but sure program of forest rebuilding.

Michigan has five national forests. Of the three in the Upper Peninsula, the Marquette National Forest is named in honor of the great missionary-explorer, Pere Marquette; the Hiawatha National Forest, a land rich in Indian history, is named for the hero of Longfellow's "Song of Hiawatha"; and the Ottawa National Forest, the largest national forest in Michigan, derives its name from the Indian word "adawe" meaning trade.

The Huron National Forest, a land also rich in Indian lore, lies in the Lower Peninsula, and is named for the once-powerful Indian tribe of that area. The word Manistee from which the Manistee National Forest was named, is the Indian equivalent of the "spirit of the woods." It is named for the river that flows through its northern portion and which, in turn, derived its name from the constant murmur of the forest at its headwaters.

The Marquette and Huron National Forests were established in 1909, the Ottawa and Hiawatha National Forests in 1931, and the Manistee National Forest in 1938. The Chief Forester of the Forest Service, located in Washington, directs the activities of these national forests. Responsibility for their administration rests with the Regional Forester in Milwaukee. On-the-ground supervision and management is by National Forest Supervisors and Rangers. The Hiawatha and Marquette, for administrative purposes, are managed as the Upper Michigan National Forests with the forest supervisor located at Escanaba. The supervisor of the Ottawa National Forest is headquartered at Ironwood. The Huron and Manistee are known as the Lower Michigan National Forests, with the forest supervisor located at Cadillac. Each forest has a number of district rangers located at designated stations—a total of 18 in Michigan.

Land for the national forests in Michigan came from two sources; (1) land withdrawn from the public domain by Presidential Proclamation, and (2) land acquired through purchase under the Federal Weeks Law.

Most of this land was "idle acres" which had been abandoned after logging and exploitation. The land for the most part had been cutover and burned, leaving a cover of brush, weeds, and cull trees. Some of this land had been cleared, farmed, and abandoned, becoming tax delinquent. A few patches of good timber missed being logged and these miraculously escaped fire.

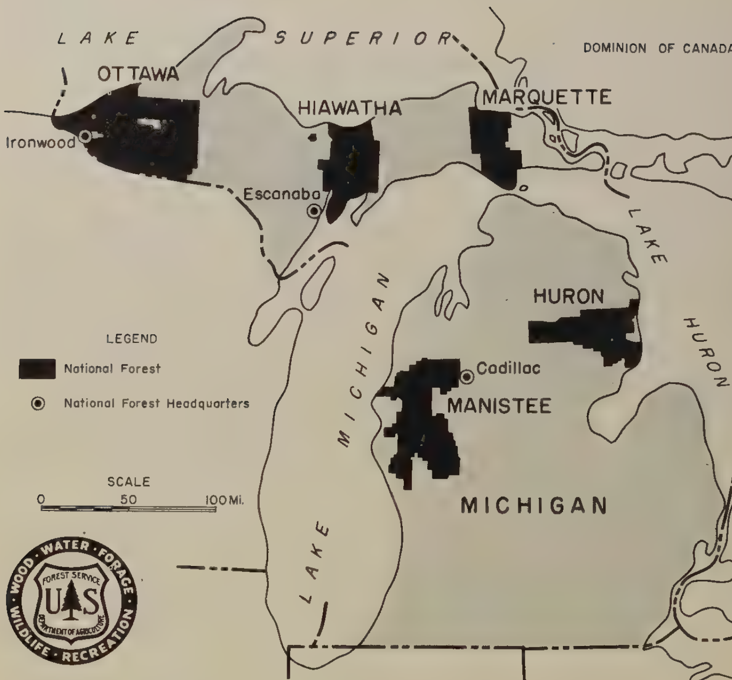

Figure 1. Michigan's National Forests.

The national forests now have progressed from an era of protection and development to one of management and production. Their boundaries embrace roughly 5,000,000 gross acres, of which 2,543,000 are now government-owned. But rebuilding national forest land to full production has been a really gigantic task. The first major problem was to reduce the acreage being burned annually. The Civilian Conservation Corps from 1933 to 1942 helped accomplish this with a peak of 56 camps, each housing 200 men. The CCC fought fires, built firebreaks and foot trails, truck trails, telephone lines, and lookout towers to aid in the war against fire.

As the control of fire advanced, aspen, jackpine, and oak took over where once the big pines stood. For years these species had little commercial value, but research and industry gradually changed this and first jackpine, then aspen, and finally oak entered the pulpwood markets.

So much for the past. What is the present situation and how about the future?

In rebuilding productivity of the land, many acres had to be planted and that work continues today. On the Manistee National Forest, for

Figure 2. "The Public's Domain," land, trees, wildlife, water, air.

instance, the planting of large "sand blows" in windswept barrens has demonstrated what can be accomplished under adverse conditions. To date, 410,300 acres have been successfully planted on national forests in Michigan. As the trees in these plantations grow, the need for sound management develops. Harmful insects and diseases must be controlled as well as fires. Natural as well as planted stands oftentimes must be "released" by removing a competing overstory of low-value trees. Weeding and thinning, as well as pruning of crop trees to insure high quality products, is needed. About 16% of all national forest land, or 425,773 acres, now have been treated.

Timber products are not the only forest resource being used, however. On national forests multiple-use and sustained yield are the basic concepts of forest management. As would be expected in a land of forest and water located within a day's drive of Detroit, Cleveland, Chicago, Milwaukee and other large cities, visitors to the national forests each summer come in large numbers. Some 1,780,000 recreation visitors now come annually as the new superhighways have made these forests more accessible to heavy centers of population. Recreation areas have become so congested that it has been necessary to expand facilities and develop new ones. Operation Outdoors, a five-year program for restoration and development of recreation facilities on national forests, is making good progress. Numbers of camp and picnic areas are now

available as follows: Upper Michigan National Forests, 23; Lower Michigan National Forests, 28; Ottawa National Forest, 22.

Important wildlife habitat is also provided in the national forests. In Michigan, more than 2,250,000 hunting and fishing licenses are sold annually; therefore maintenance of fish and game populations is of special significance and this work is conducted in cooperation with the Michigan Department of Conservation. One problem of major importance is that of balancing deer populations with available deer food. Overpopulation of deer has substantially reduced the amount of deer browse on national forests, and there has been starvation in some areas. There are an estimated 150,000 - 200,000 deer in the national forests in Michigan. Habitat for fish and other game is receiving growing concern in the management of national forests. Responsibility for the protection and utilization of all this wildlife rests with the Michigan Department of Conservation.

Earnings from national forests in Michigan have substantially increased in the last 20 years. Using sustained yield management, the amount of wood that can be safely harvested has increased over a period of years as the forest has developed under sound management. With increased reforestation and stand improvement, however, these forests could produce substantially more timber products than they do at present. During fiscal year 1959, some 13,000,000 board feet and 225,000 cords of pulp were harvested. Receipts were more than $920,000 in the same year. The community shares in these receipts with 35% being returned for improvements in the forest, 25% being given to the county and 10% going to the national forests. Community benefits derived from payrolls in local wood-using industries are particularly important. Revenue from recreation, including hunting and fishing, is another local contribution.

Thus, national forests in Michigan are recreating the rich forests of earlier days. At the same time, they are providing growing recreation for the public. Brush is giving way to trees, trees are growing in size, and timber volume is increasing year after year. Under multiple-use and sustained-yield management plans, benefits continue to accumulate at an ever-accelerating rate. They build sustaining resources for the future and contribute heavily to local communities. Vacationers and sportsmen have a vast unfenced recreation area to enjoy. With care and intelligent use these great national forest resources can be made to serve present needs and the requirements of generations to come. In short, the best story is in the future, and that tale is still to be written.

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THE EFFECT OF POPULATION PRESSURES ON TIMBER NEEDS IN THE UNITED STATES

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One of the most astounding social, political, and economic facts of this century has been the rapid increase in population. The population of the United States today is over twice that of the year 1900 and the latest projections indicate that it will almost double in the 40 years between now and the year 2000. The impact of this tremendous increase in the number of people will certainly affect our uses of the available forest land. Add to this situation the fact that per capita real incomes have risen markedly, and seem likely to double present levels by 2000. Twice as many people with twice as high real incomes per capita would call for four times the total economic output of the nation. How then, can a relatively fixed area of forest land meet the demands of a rapidly growing economy?

The detailed analysis of timber growth and potential demands published by the U.S. Department of Agriculture - Forest Service, in Timber Resources For America's Future, indicates that sawtimber growth needed to meet prospective timber demands by the year 2000 is likely to be about 105 billion board feet, or about twice the present level. Projected demand for all timber products indicates increases over 1952 consumption of 83 per cent for the year 2000. The challenge to America's foresters, timberland owners, and Americans in general, is to make certain that this nation has an adequate supply of forest products in the future.

Over half of the nation's commerical forest land is in $4\frac{1}{2}$ million comparatively small tracts owned by farmers, businessmen, professional people, and others not associated with forest industry. These small ownerships have the poorest cutover conditions, are the least adequately protected from fire and have the greatest area of poorly stocked and non-stocked lands that need to be planted. They also have the largest area where stand improvement is needed to improve growth, species composition and tree quality. Surprisingly enough, these small woodlands are also the largest in timber production potential. Thus, the key to adequate timber supplies in the future lies in the prompt acceleration in forestry—with particular emphasis on small ownerships.

Accelerated Reforestation

In spite of the mounting interest in planting during recent years, the rate of reforestation must be stepped up substantially if our wood requirements of the future are to be met. Forty-eight million acres are in need of planting or seeding as quickly as possible. More than four-fifths of these idle lands are in the East, mostly in small private ownerships.

Faster, cheaper methods of forest regeneration are being developed. Direct seeding has now moved out of the exploratory stage and offers excellent opportunity for low cost regeneration under certain climatic and biotic conditions. Early efforts at direct seeding were usually unsatisfactory due to seed losses to birds and rodents. Since the development of a chemical seed-coating repellent many areas have been successfully stocked through direct seeding. Further development and expansion of the direct seeding method of regeneration should expedite the reforestation program of the future.

If adequately reforested, the area in need of planting or seeding might eventually add about 8 billion board feet annually to the nation's timber supplies.

Forest tree breeding offers tremendous possibilities to raise quality and increase the rate of tree growth in our forests of the future. Geneticists and tree breeders have demonstrated the practical possibilities of improved varieties. Studies have shown that stem form and branch size—both important factors in tree quality—are strongly controlled genetically.

Hybrids from four southern pines have been made by controlled pollination and are currently being tested to determine which desirable characters of the parental species are transmitted. It has already been shown that hybrids between longleaf pine and either loblolly pine or slash pine exhibit early height growth in contrast to longleaf pine seedlings which may not grow out of the grass stage for several years.

It is not conceivable that tree hybrids will bring about the remarkable production increases we have witnessed in hybrid corn or other vegetative hybrids, but there are many indications that "superior" trees will be planted extensively within the next decade.

Superior trees, in all probability, will be developed for the principal timber-producing areas and for different end products. These trees will be much more productive than the usual "wild" strains. They will, in many instances, produce timber that is of higher quality, more resistant to disease, faster growing, of better vigor and easier to re-establish.

Improving Stocking and Quality

There are 114 million acres of commercial forest land in the United States that are less than 40 per cent stocked. This is about one-fourth of the total commercial forest area, and it includes nearly 42 million acres that are less than 10 per cent stocked. Thus one-fourth of our forest land is not now growing, and will not grow, timber to anywhere near the productive capacity of the land unless stocking is greatly improved.

There is also substantial evidence that standing timber is declining in quality; two-thirds of the eastern hardwood sawtimber, for example, would probably classify as poor Grade 3 logs. Medium projected demand for millwork, siding, furniture, veneer and other timber products requiring substantial proportions of high quality material in the year 2000 is estimated at two and one-half times 1952 consumption. Despite the very considerable technological advances that offset in part the need for quality, the outlook appears to be for a greater total demand for quality timber.

To im[illegible]cking and quality of our forests we must immediately inte[illegible]anagement on much more of our forest land with concentration of effort on the small ownerships. Improved harvest cutting practices, cultural treatment of immature stands, conversion to valuable species and other intensive management practices are urgently needed. Foresters responsible for management of industrial forests and public forests have made notable progress in this field but the small forest ownerships show an alarming need for improved management.

Other cultural measures are possible; fertilization of forest lands and extensive use of herbicides to eliminate undesirable species may have considerable effect on growth and stocking. An adequate system of access ways or minor roads could contribute substantially to more intensive forest management.

Control of Destructive Agents

Mortality, plus the calculated loss of growth in timber caused by fire, disease, insects, weather and other factors amounts to over 40 billion board feet per year or nearly the same as net growth of sawtimber. The reduction of these losses presents a fertile field for progress in providing adequate wood supplies for the future. Disease, insects, and fire are the most important. Probably the principal reason fire ranks below disease and insects is because of the tremendous advances made in forest fire prevention and control in recent years, but fire is still an important menance to forestry. If present fire control efforts were relaxed, fire would soon become the number one destroyer of the forest.

Tree diseases cause the greatest loss and offer the most resistance to direct control. Continued and intensified research will be needed before effective control of many tree diseases over extensive areas is economically feasible.

Most insects are now subject to control and giant strides have been taken in recent years to reduce forest losses from insects. Diligent patrol and control over all types of ownership within areas of infestation could bring about additional reductions in losses.

Timber owners are becoming aware of the fact that many losses can be reduced by indirect methods such as improved cutting practices and timber stand improvement treatment. Forest tree improvement research aimed at development of resistant strains of trees holds promise for the future.

Better Utilization

Some forest industries, backed by research and experience have made substantial progress in more efficient use of wood. However, too much timber that is cut is still being left unused in the forest and in the mill.

Logging and plant residues can, of course, never be completely eliminated nor can dead trees and culls be completely salvaged. Better markets, the introduction of new products and the development of new equipment for harvesting and processing all bring about more efficient timber use. Progress in each of these fields will help in meeting future timber needs.

The Outlook

Much progress has been made in forestry in recent years and even greater progress will be made in the future. Forestry is not a short-time proposition. Where this nation stands in timber supply by the year 2000 will depend upon how rapidly we bring about a much more intensive mangement of our forests. Recent encouraging forestry trends will continue. But this is not enough. Acceleration of these trends is vital, and to an intensity far beyond anything we have done thus far. The potential of the land is adequate. The opportunity is there. Our immediate need is to narrow the gap between what foresters know about timber growing and what the average landowner practices.

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SOME TEMPERATURE AND PHOTOPERIOD EFFECTS ON GROWTH OF EASTERN REDCEDAR SEEDLINGS[1]

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One of the purposes of photoperiod experiments with tree seedlings at the University of Nebraska is to determine feasibility of using supplemental light to stimulate growth of seedlings in the nursery. We found that supplemental light increased and sustained height growth of eastern redcedar, Juniperus virginiana L., seedlings at a minimum temperature of 75°F in the greenhouse and in environment control chambers. Supplemental light increased height growth in early summer in an outdoor environment at Lincoln but failed to sustain it after mid-August (unpublished data of authors). Minimum temperatures by the middle of August reach the low 50's (F) at Lincoln.

Minimum temperatures during summer average even lower at many nursery locations in the northern great plains. Thus it appears that the lower temperatures of late summer and fall might limit stimulation of growth that could be expected by providing supplemental light.

Kramer (1957) and Nitsch (1957) have reviewed the literature on effect of temperature on woody plant growth and the relationship to photoperiod. It has been demonstrated that thermoperiodism, the reaction of plants to various combinations of day and night temperatures, is exhibited by many tree species. Amount of growth and length of growing season may be modified by changing the length and amplitude of cycle of day and night temperatures. Different diurnal temperature cycles may intensify or nullify the effects of photoperiod on growth.

Juniperus horizontalis Moench. under 18-hour photoperiod made maximum growth at 70°F night temperature, but under continuous light the maximum growth occurred at "night" period temperature of 50°F (Waxman, 1957). Thus photoperiod may determine the most effective temperature combinations for growth. On the other hand, light intensity may also influence optimal night temperature as was demonstrated for tomatoes (Went, 1953).

Growth of hemlock, Tsuga canadensis (L.) Carr. seedlings benefited from diurnal temperature fluctuations within a range of 62 to 80°F.

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However, response to different temperature and light combinations was variable among ecotypes (Olson et al., 1959).

This paper reports results of an experiment set up to determine how eastern redcedar seedlings respond to: (1) three different night temperatures under conditions of high day temperature and long photoperiod, and (2) long photoperiod versus normal day under conditions of high day and moderate night temperatures.

MATERIALS AND METHODS

Thirty, 1-year-old potted eastern redcedar seedlings of central Nebraska source, selected for uniform size (top length 4.0 to 5.8 cm), were placed in each of four environmental control chambers described by Chapman (1956). Sandy loam soil was used for potting. Treatment data are given in Table 1. Light source in each chamber consisted of one blue, one red, and six 30-watt standard cool white fluorescent tubes.

Table 1. Treatments and environmental conditions in growth chambers.

Treatment		Light	Ave. light intensity	Temperature			
Day length	Night temp.	period (hours)	at pot top (foot-candles)	(14 hours) °C	°F	(10 hours) °C	°F
Long	Moderate	20	500	32	90	15	59
Long	Hot	20	490	32	90	27	81
Normal	Moderate	14	545	32	90	15	59
Long	Cold	20	535	32	90	7	45

In all treatments a light period temperature of 90°F was maintained for 14 hours. Minimum or night temperatures were maintained for 10 hours to complete the cycle. Recording thermographs and thermometers provided a check on temperature throughout the experiment. Soil temperature and humidity were not controlled. Heights from cotyledon node to tip were measured every 2 weeks at which time seedlings were shifted randomly to different positions within the chambers.

At the end of 24 weeks, the seedlings were unpotted, weighed, and top-root ratios in terms of volume determined by a water displacement method. They were repotted and placed outdoors in a 50% shade house with no supplement light for a 6-month period, May to October. Heights, weights, and top-root ratios were again obtained.

RESULTS AND DISCUSSION

Growth Chambers

Treatments caused different top growth responses (Fig.1). Average height of seedlings at the end of long-moderate treatment was nearly twice that of long-cold (all references to treatments are abbreviated as shown in Table 1). The different responses became evident after only 8 weeks of treatment. All differences in top growth, except between

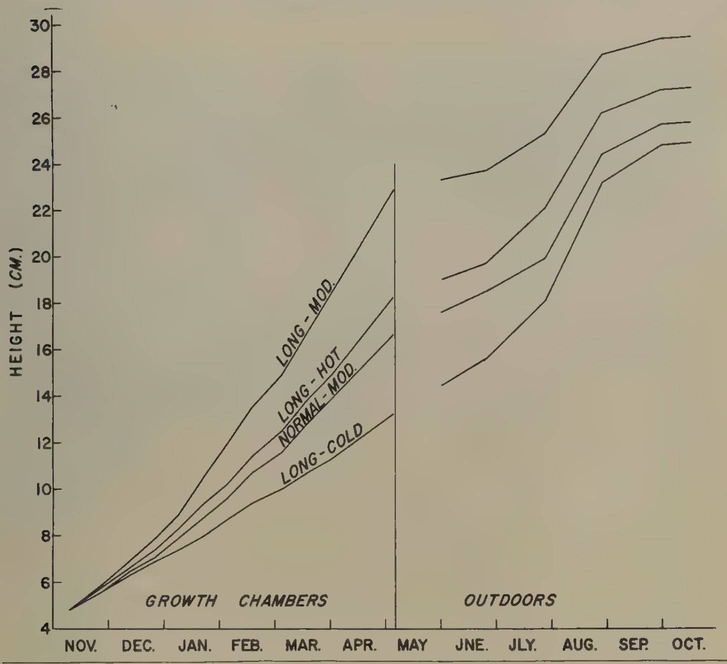

Figure 1. Average height of eastern redcedar seedlings by treatment and time.

normal-moderate and long-hot, were highly significant (Table 2). The long photoperiod increased growth over normal light period at the same temperature levels (90°-59°F).

Individual tree response was more variable within the long-cold than in the other treatments (Fig. 2). Variance for long-cold was 19.5 compared to only 10.7 for long-hot. Variation in response of seedlings due to genetic differences was apparently accentuated by cold night temperatures. In contrast, the more uniform temperature regime of the long-hot treatment obscured this variation.

Total seedling weights of the long-moderate and long-hot treatments were significantly different than the weights of normal-moderate and long-cold. The different responses of height growth versus total weight were due to differences in distribution of growth. For example the proportion of root volume to total volume was greater under long day with cold night than under normal day with moderate night temperature. Root growth of the other two treatments increased, but not in proportion to top growth (Fig.3). As a result, the seedlings of long-cold, despite their slow top growth, had the lowest top-root ratio and were therefore better balanced than the other treatments (Table 2).

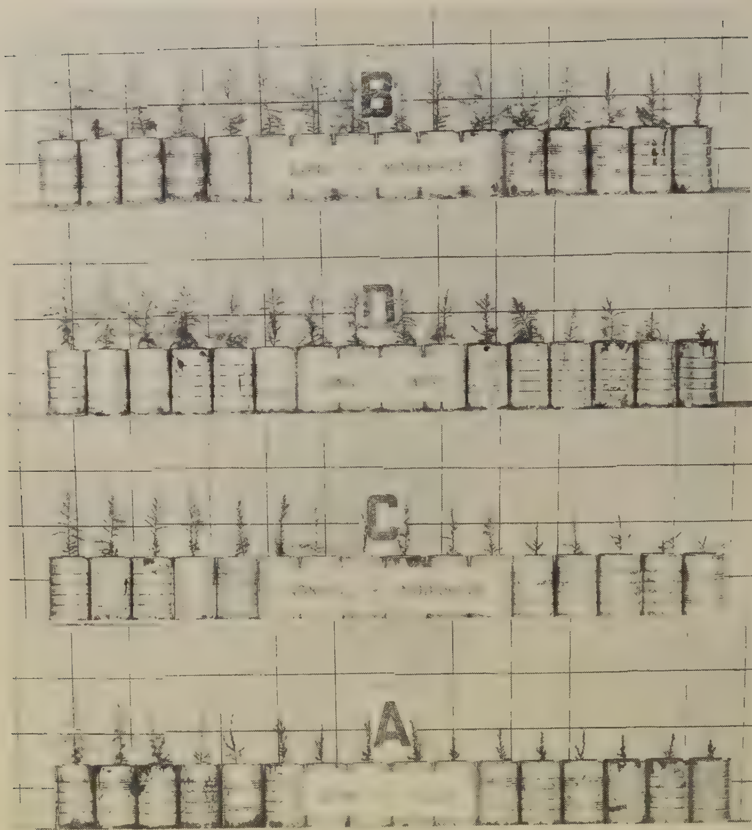

Figure 2. Eastern redcedar seedlings at end of 24 weeks in growth chambers.

Outdoors

During the first two months outdoors the rate of seedling height growth decreased in all treatments, except the long-cold (Fig.1). The seedlings in this treatment responded more quickly to outdoor environment and grew faster than the other treatments. The greatest increase in height growth for all treatments was made during the month of August.

Decided changes took place in distribution of growth on the seedlings at the end of six months. Differences in total height were less, although the seedlings of the long-moderate treatment, which had shown greatest response, were still taller than those of other treatments (Table 2).

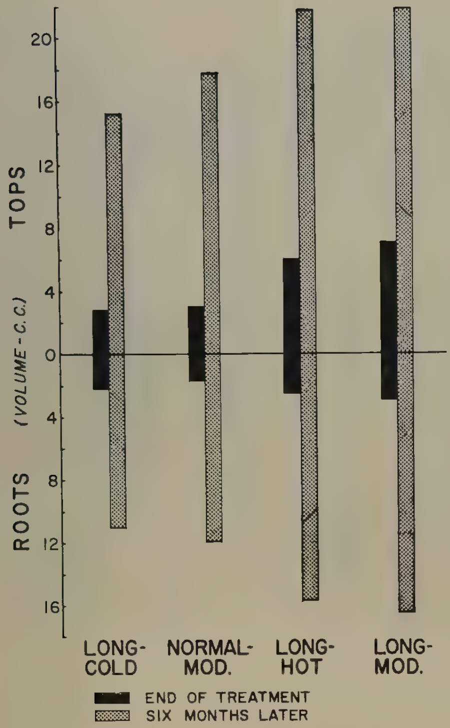

Figure 3. Average top and root volumes of eastern redcedar seedlings after 24 weeks treatment and 24 weeks outdoors.

Table 2. Average height, weight, and top-root ratio of eastern redcedar seedlings by treatments.

Treatment: Day length	Treatment: Night temp.	Top height: Initial	Top height: End of treatment	Top height: 24 weeks later	Total weight: End of treatment	Total weight: 24 weeks later	Top-root ratio: End of treatment	Top-root ratio: 24 weeks later
		Centimeters			Grams		Ratio	
Long	Moderate	4.8	22.0	29.5	7.8	35.8	2.66	1.39
Long	Hot	4.8	17.7	27.3	6.5	34.8	2.48	1.44
Normal	Moderate	4.8	16.2	25.8	3.5	27.0	2.00	1.59
Long	Cold	4.8	12.9	24.8	4.0	23.9	1.23	1.40

Lines connect means that are not significantly different (LSR .01).

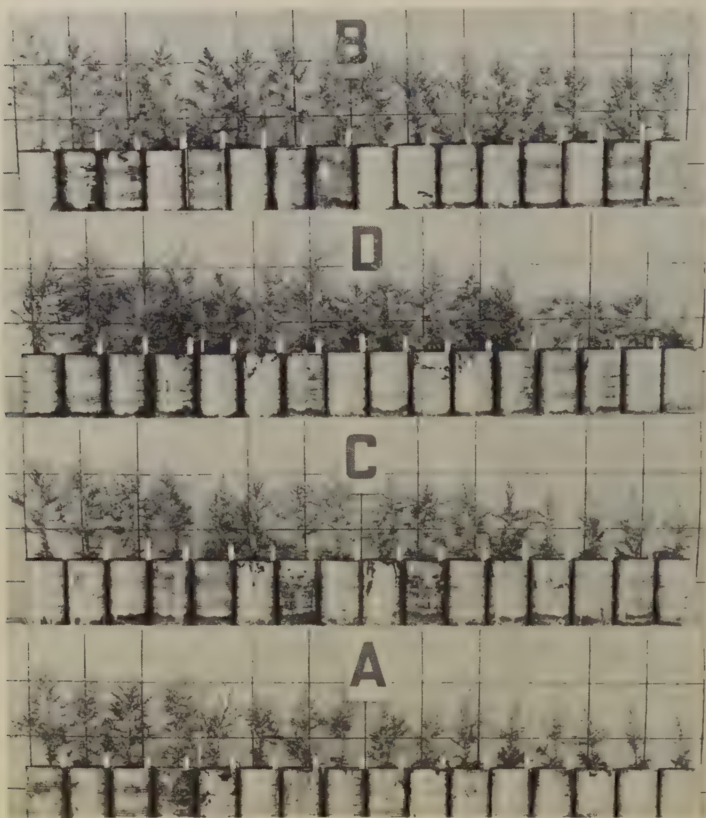

Figure 4. Same seedlings in same order as Figure 2 at end of 24 weeks outdoors.

The shortest seedlings (long-cold treatment) grew the most in height. The outdoor environment tended to reduce variability in seedling height within all treatments (Fig. 4). The extreme variability in seedling height brought about by long-cold treatment was reduced to the extent that the variance was no greater than that of the seedlings of the long-hot treatment.

Total weight relationship among treatments was not changed by outdoor environment. Root growth was greatest on trees that had the largest tops (long-moderate) and least on trees with the shortest tops (long-cold), tending to equalize top-root ratios after six months outdoors (Table 2 and Fig. 3).

SUMMARY

Eastern redcedar seedlings grown at daytime temperatures of 90°F responded differently in top and root growth to four combinations of night temperature and photoperiod.

Greatest growth and highest top-root ratios were obtained by a diurnal fluctuation from 90° to 59°F with a 20-hour photoperiod (long-moderate).

A diurnal fluctuation from 90° to 45°F with a 20-hour photoperiod (long-cold) produced the smallest seedlings with the lowest top-root ratios.

Heights and weights at 59°F (moderate) night temperature were significantly greater under 20-hour (long) photoperiod than under 14-hour (normal) photoperiod.

Variation in growth response within treatment was greatest under the 90° to 45°F (long-cold) and least under the 90° to 80°F (long-hot) temperature regime.

Seedling heights and top-root ratios tended to equalize after 6 months in an outdoor environment, but significant differences in total weight did not change.

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INTENSIVE CONTROL IN LOGGING PONDEROSA PINE

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Approximately 55% of the mature ponderosa pine timber type on the Deschutes National Forest in central Oregon is either adequately stocked or overstocked with understory reproduction. Although seemingly a desirable condition, all is not as rosy as may appear. There remains the problem of harvesting the mature timber and still leaving enough reproduction to give the forest manager a good selection of young trees for future growth.

Natural stands of ponderosa pine (Pinus ponderosa Laws.) in the West usually occur in even-aged groups ranging in size from less than 1 acre to approximately 50 acres. These timber groups can broadly be classed into reproduction, immature, mature, and overmature. Many mature and overmature groups have densely stocked understories of sapling and pole-sized trees (Figure 1). This natural group occurrence of overstory and understory lends itself remarkably well to a system of management known as unit area control, or "detailed control of stocking on small areas" (Hallin 1954). Increasing acceptance of the unit area concept in management has intensified the urgent need for guidelines for improving logging techniques.

Logging either large or small units of mature overstory will inevitably result in some loss of understory growing stock. This loss, however, is not of concern if it is not excessive and is well distributed throughout the stand. It is conceivable that proper control of reproduction loss may actually reduce stand improvement costs. Parallel felling, for example, will kill many young trees which would have been cut in thinning later on but will, under proper control, leave an adequate selection of young trees for future growth. Thus, actual thinning effort is reduced.

Uncontrolled logging in ponderosa pine usually results in leaving small units completely devastated and large units understocked. Our problem, therefore, is to find a way to reduce and distribute reproduction loss to maintain adequate stocking.

Observed Losses

Logging damage to ponderosa pine reproduction has not been extensively studied. Fowells and Shubert (1951) observed 72% destruction of reproduction (3.5 inches d.b.h. and less) in a mixed ponderosa pine and fir logging show in California. Mowat (1940) reported a 40% loss of reproduction (below pole size) in a similar stand with a smaller original volume and cut. Loss percentages such as this can be misleading if the

Figure 1. Typical old-growth ponderosa pine with sapling understory.

distribution of this loss is not explained. For example, a 70% loss of 10,000 sapling trees per acre still leaves 3,000 stems per acre—an apparently good prospect for selecting leave trees. The above researchers report a patchwise distribution of losses, with many areas completely devoid of reproduction.

At the present time, areas lacking in reproduction present a difficult regeneration problem. Survival of planted stock in many areas has been extremely low and repeated plantings have been necessary. Fill-in planting after logging is an expensive operation costing from 15 to 30 dollars per acre, depending on the number of trees necessary to bring the acre up to stocking standards.

An Example of Good Control

During 1957, on the Pringle Falls Experimental Forest in central Oregon, 140 acres of timber were set aside to be logged of all merchantable trees. The area consisted mostly of typical old growth and some immature ponderosa pine, averaging 17 M.b.f. per acre. Five cutting units, ranging in size from 6.5 to 65 acres, were laid out to facilitate the establishment of spacing studies in the sapling-sized ponderosa pine understory.

For experimental purposes, it was necessary to save enough good

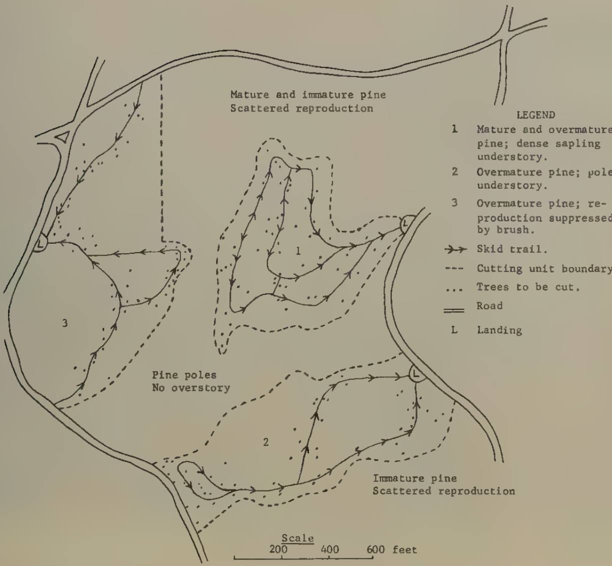

Figure 2. Cutting units on the Pringle Falls Experimental Forest, Pacific Northwest Forest and Range Experiment Station.

understory saplings after logging to make up a stand spaced 6 x 6 feet throughout each of 47 half-acre plots. The desired spacing outside the plot boundaries was 13 x 13 feet. As one can imagine, logging of the study plots and the surrounding area presented a unique problem. By intensive control of logging practice, however, damage was held to a remarkably low level. From this experience have come some rather simple techniques which may be applied to logging clear-cut units in ponderosa pine.

Suggested Procedures for Improved Logging Control

Control may be divided into 7 steps:

1. Logging plan.

It is important that the logging plan be prepared jointly by the logging superintendent and the land manager.

An adequate plan may consist of a detailed map based on woods observation, showing the location of landings, skidtrails, and cutting units and the order in which units are to be cut (Figure 2). Operating specifications, such as skidtrail width and tractor size, can be more effectively implemented if included in the sale contract.

2. Skidtrail location.

Trails should be 100 to 150 feet apart, preferably on the contour with as little grade as possible. Red or yellow ribbon flagging was found to be convenient for this purpose.

3. Trail "skinning."

Skidtrails are "skinned out" in advance of cutting to facilitate felling trees for convenient yarding. The trail helps to orient timber markers, fallers, and tractor operators, thus giving the whole operation a base from which to work.

Tractors should not be larger than a D-7 caterpillar or its equivalent. One faller should work ahead of the tractor, locating trail markers and bucking windfalls. Skidtrail width should be limited to about 12 feet or some other predetermined width commensurate with the desired spacing of residual reproduction.

4. Marking.

Tree marking, indicating direction of fall, is especially important during initial stages of logging when clear felling space is limited. As operators become familiar with this method, marking trees may not be necessary if boundaries of the units are indicated in the woods.

5. Felling.

Positioning of tree about 30° to the lead of skidtrails provides a minimum of maneuvering to extract logs. In areas with a high-volume cut, it may be necessary to log in stages in order to reduce breakage. Also, fallers may be able to take advantage of openings created by the first stage. Considerable wedging of trees is usually necessary. Fallers can become extremely skillful in this operation and surprisingly good results can follow.

6. Skidding and Equipment Needed.

Crawler or rubber-tired tractors of D-7 size without dozer blades were found satisfactory for this type of logging. In the study cited above, the rubber-tired skidder was efficient except in snow, where traction was greatly reduced (Figure 3). Ground skidding in light pumice soils may produce deep gullies from only 2 or 3 turns of logs. Use of small rubber-tired skidding arches with a capacity of 2.5 M b.f. in 32-foot logs worked satisfactorily in the Pringle Falls operation. Tractors should be equipped with drums and 50 to 75 feet of cable. Frequent line pulling is recommended in order to reach logs without moving tractors off skidtrails. This practice may be relaxed in areas of sparse or no reproduction.

Skidtrails should be located so that sharp turnarounds are not necessary. In high-volume cuts they become larger and larger with each turn of logs. The alternative is to break through to another skidtrail or make a large enough loop so that the spacing objective is maintained. The tractor operator may then work around on his turn of logs, reversing his direction only at the landing.

Figure 3. Rubber-tired skidder yarding a 32-foot log from dense reproduction.

7. Landings.
A few large landings are less destructive than many small ones, especially when 32-foot log lengths are being cut. Size of landing will to some extent depend on maneuverability of the loading machine. Generally much less space is required if logs are decked parallel with the road. "Hot logging" with repeated use of a given landing is preferable to cold decking.

Cost Considerations

Imposing intensive control regulations will raise logging costs. However, some operators may find that the systematics of control will improve their log production rates and at least partly offset the added cost of control measures. The landowner "buys" this logging control through a reduction in stumpage sale price or in lower conversion profit if he does his own logging.

If logging is not controlled, fill-in planting becomes necessary to attain maximum growth per acre. What is lost by this approach, assuming our planting is a success? — About 20 years of growth, or 14% of our future rotation time, if saplings are destroyed; or 50 years and 36% of rotation age if the loss is composed of poles. Discounted back from ultimate values, this in itself would be an appreciable amount. However, due to the pressures of heavy deer and rodent populations in central Oregon,

many plantings have resulted in only 5 to 10% survival the first year. Yearly fill-in plantings could easily bring stocking costs up to around \$85 per acre. The combined discounted value of established growing stock and the cost of regeneration elevates the value of established reproduction high above currently accepted levels in central Oregon.

The logging experience on the experimental forest showed that good control should cost the landowner about \$2.50 per M.b.f. This was equivalent to \$42.50 per acre in the case of the Pringle Falls study, where the average-sized 16-foot log was only 17 inches in diameter. In typical unit area cuttings, this average diameter would probably be much larger and the volume would be distributed on fewer trees. Thus, control costs per M.b.f. would be lower.

Psychology of Control

To administrate a successful logging control program, there must be complete understanding between operator and forest manager. A change in logging procedure entailing more work and without apparent purpose immediately antagonizes and often produces the opposite of the effect intended. The full scope of the purpose of control cannot be put into the usual sale contract and must be impressed upon the logger in the woods. Personal, on-the-spot explanation as to the reasoning behind each change will produce remarkable results both in attitude and accomplishment.

Summary Statement

Until the regeneration problem is solved, intensive logging control may offer the best approach to maintaining adequate growing stock in the mature and overmature ponderosa pine stands in central Oregon. It is likely that the techniques described above can be further refined through additional tests. However, the procedure is sound and can probably be adapted to varying stand conditions and topography.

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RADIOACTIVE PHOSPHORUS AS A TRANSLOCATION TRACER IN SOME SUCCULENT PLANTS

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Recently, a considerable amount of work has been done using radioactive tracers in plants. Unfortunately, most of this work must be conducted by well-established botanists and biochemists due to the dangers involved in handling radioactive isotopes.

This particular experiment illustrates the use of radioactive tracers for measuring transpiration rates in succulent plants. However, the same basic principles of translocation in succulent plants may also apply to woody plants, including trees. Therefore, the localization of injected isotopes, to be used as tracers, might permit a proper rate measurement of translocation in trees as it did in succulent plants. Future research will be necessary to arrive at any definite results with trees.

METHODS AND PROCEDURE

One millicurie (mc) or 50 cc of phosphorus-32 (P^{32}) was supplied by the Yale University Isotopes Committee, from Oak Ridge, Tennessee. P^{32} is a B-particle[1] emitter, and has a half-life[2] of 14.3 days. Other tracer elements could have been used, but were less desirable due to the hazards created by their longer half-lives. The primary P^{32} was stored in a metal container in a wooden cabinet, and behind a well marked, locked door. Aliquots of varying activities were pipetted from the primary quantity of P^{32} for each experiment.

Three genera of plants were used: geranium (Geranium zonale, Linn.), cyperus (Cyperus alternifolius, Linn.), and balsam (Melissa officinalis, Linn.). These plants were cut under water to avoid air introduction to their vessels, and their bases were transferred to 125 ml flasks while being kept under water. The flasks were then drained to levels of 50 ml. The P^{32} aliquots were poured into the water, and the openings of the flasks containing the highly diluted P^{32} and plants were then sealed with aluminum foil to aid in filtering out the B-particle radiation.

Later experiments required a dilution of the P^{32}-water solution with KH_2PO_4 (Potassium orthophosphate "di-H") to avoid the attainment of early equilibrium between the plant P^{32} and the solution P^{32}. This was necessary because the stems and other plant organs obviously were incorporating the P^{32} into their metabolic processes before it ever reached the leaves, and, consequently, the equilibrium was attained at relatively low levels of P^{32} in the leaves. The dilution with KH_2PO_4 added non-activated P to the system for the metabolic processes, but didn't increase the activity which temporarily solved the problem.

[1,2] See Appendix.

A possibility for failure of the P^{32} to accumulate in the leaves during translocation is that tyloses may be formed in the vascular canals, thus, reducing the P^{32} quantity reaching the leaves. Many other anatomical and physiological problems may also exist.

Another problem was that the base solution emitted enough radiation to cause errors in the radioactivity being measured at the leaves, even though aluminum foil was used to cover the base solution. Therefore, a shield extending beyond the end of the counter tube and opened to the leaf became necessary. First, a wooden box over the leaf and counter tube was tried which succeeded in eliminating the outside radiation, but prevented the leaf from obtaining the necessary light, humidity conditions, and temperature for normal transpiration. A pipe was then placed over the end of the counter tube which cutout the outside radiation and also permitted the leaf to be exposed to the natural conditions.

Short geranium stems (approximately 6 inches from the stem-cut to the leaf petiole base) proved to be the most successful plant section for the experiment. The other two species, balsam and cyperus both responded favorably to the accumulation of P^{32} in their leaves, but the balsam seemed to be somewhat slower, and the cyperus has long narrow leaves (which are awkward to work over the pipe end) and appears to have its vascular system partially destroyed when the slightest bend is made in its stem upon preparation. This latter phenomenon partially prevents the P^{32} from reaching the leaves.

A succulent geranium plant was cut under water at a location on the stem approximately six inches below the base of the petiole (3 inches in length) of the leaf to be used. The base of the plant was then placed in a 125 ml Erlenmeyer flask containing 50 ml of water while keeping the incised base of the stem under water. The plant was next defoliated to one leaf. Fifty ml of $2 \times 10^{-3}M$ KH_2PO_4 were then added to the water making a solution of 100 ml of $1 \times 10^{-3}M$ KH_2PO_4. A Geiger-Müller counting-tube was placed in the pipe so that the pipe extended 3 inches beyond the end of the window of the tube. The background radiation was recorded and the average was later subtracted from the total counts. Approximately 5 microcuries (μc) of P^{32} were added to the base solution containing the plant, and the top of the flask was immediately sealed with aluminum foil. The time was recorded at the time of the P^{32} introduction. Then, the leaf was placed over the end of the pipe and taped from the outside only, so as not to interfere with the normal transpiration. A light and fan (to control the humidity) may be turned on or off. The counts per minute were recorded every minute and plotted over the time from the application of the P^{32} (Figure 1).

RESULTS AND DISCUSSION

The slope of the curve indicates the rate of transpiration. Mathematical calculations could be made with regard to the amount of water being transpired to deposit the P^{32} in the leaf at various radiations, and knowing this, the rate of its travel through the plant could be roughly estimated. However, many passageways may exist for the water and P^{32} which would make this estimation highly inaccurate or invalid.

When the rates of more than one leaf are compared, the leaves' sur-

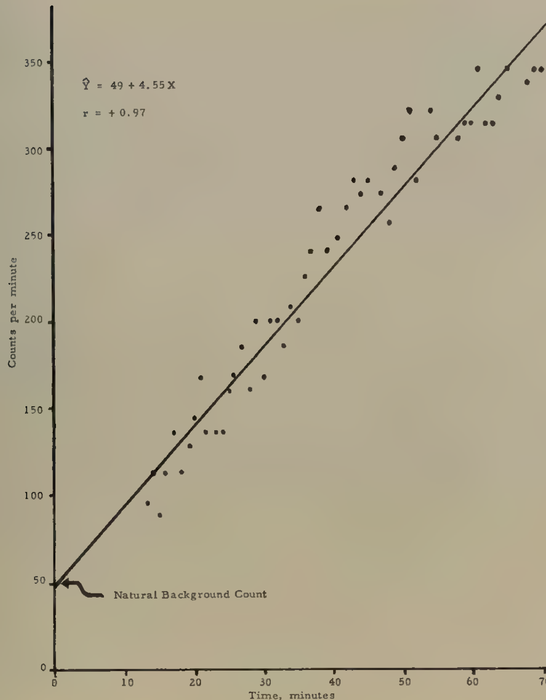

Figure 1. Relation between time after application of P^{32} to the base solution and the counts per minute registered on the Geiger-Müller counter from a geranium leaf.

face areas exposed to the pipe end must be considered. The quantity of activity (in counts per minute) of each leaf should be directly proportional to the leaf area exposed to the pipe end.

Future possibilities include measuring the rate of transpiration under varying conditions of light intensity, temperature, wind, and humidity by using P^{32} tracers. This can be accomplished by placing the plants under these conditions and measuring the slopes of the resulting curves.

Similar experiments with cyperus and balsam plants yielded similar results to those obtained for geraniums. However, the results and curves obtained for geranium best illustrate the correlation between time after P^{32} introduction and P^{32} accumulation in the leaves.

Many safety precautions are necessary for safe handling of radioactive isotopes. These are listed in any literature discussing the use of isotopes in biological research. Since this experiment involved only low activities, aluminum foil sufficed as shielding. This foil was also used to cover the working area as a safeguard against spillage. Rubber gloves,

a face mask, tongs, and a bulb pipette are necessary laboratory equipment for safety precautions. All disposal of activated material should follow the instructions outlined in the handbooks required to be present in the working area by the safety regulations of the U.S. Atomic Energy Commission. Their regulations are known as 10 CFR 30 - "Licensing of Byproduct Material," published in the Federal Register January 11, 1956; and 10 CFR 20 - "Standards for Protection against Radiation," published January 29, 1957. Isolation and marking of used equipment and spillage areas should also be practiced. Perhaps a clean laboratory is the most important requirement for safe handling of radioactive isotopes.

APPENDIX

1. B-particle - essentially an electron.
2. Half-life - the time required for the disintegrations to reduce the activity of the P^{32} to one-half its original level at the beginning of this time period.
3. Roentgen - the quantity of X or γ radiation so that the associated corpuscular emission per 0.001293 grams of air produces, in air, ions carrying one elctrostatic unit of quantity of either sign.
4. Curie - a measure of isotope quantity and designating the number of disintegrations per second (3.7×10^{10} disintegrations per second).

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CONTROLLING OAKS WITH STEM-APPLIED HERBICIDES

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INTRODUCTION

Various techniques for killing undesirable oaks with herbicides have been widely tested and reported in recent years, often with contradictory results. Because most studies test a limited number of variables, and the mechanism of kill with herbicides is not well understood, the wide variation in results is not surprising. In order to clarify some of the conflicting recommendations extant, an extensive study was conducted recently in southern Missouri to compare several chemical-mechanical treatments reported to be effective on oaks. Important variables considered were size of tree, month of application, and concentration of herbicide.

All the treatments tested were "hand" methods. These have certain advantages over the easier, cheaper, and faster aerial spraying methods. For one thing, hand treatments can be selective, which is critical where only part of the trees in a stand are to be killed. Hand treatments can be applied and are effective during most of the year while aerial spraying must be done when the vegetation is in full foliage.

THE STUDY

The study was begun in the spring of 1952, a year of below-normal rainfall in the Missouri Ozarks. Herbicides used were 2, 4, 5-T (2, 4, 5-Trichlorophenoxyacetic acid), ammate (ammonium sulfamate), and monuron (3-(p-chlorophenyl)-1, 1-dimethylurea). Two study areas provided a wide range in tree diameters. Most trees were on the Mark Twain National Forest area near Rolla; some of the larger trees were about 40 miles away on the Clark National Forest area near Salem.

The study tested 8 chemical-mechanical treatments on 4 oak species of 5 diameter classes in 3 different months. More than 14,000 numbered trees were used.

Species tested were white oak (Quercus alba L.), blackjack oak (Q. marilandica Muenchh.), black oak (Q. velutina Lam.), and post oak (Q. stellata Wangenh.). Five diameter classes were used: 1, 2-3, 4-6, 7-10, and 11-inch and larger trees. The 8 chemical treatments (Table 1) each were applied in February, the late dormant season, in June, the season of most rapid growth; and in November, the early dormant season.

[1] Maintained in cooperation with the University of Missouri Agricultural Experiment Station, Columbia, Missouri.

Table 1. Description of the eight treatments used.

Treatment Code	Herbicide	Concentration	Carrier	Method of Application
Ammate; 4 lb; LF	Ammate	4 lbs/gal	Water	Low frill (6")
Ammate; 4 lb; HF	Ammate	4 lbs/gal	Water	High frill (30")
2, 4, 5-T; 12.5 lb; LF	2, 4, 5-T	12.5 lbs a.h.g.[a]	No. 1 fuel oil	Low frill
2, 4, 5-T; 12.5 lb; BS	2, 4, 5-T	12.5 lbs a.h.g.	No. 1 fuel oil	Basal spray
2, 4, 5-T; 50 lb; LF	2, 4, 5-T	50 lbs a.h.g.	No. 1 fuel oil	Low frill
2, 4, 5-T; 50 lb; BS	2, 4, 5-T	50 lbs a.h.g.	No. 1 fuel oil	Basal spray
Monuron; 0.5 lb; LF	Monuron	0.5 lbs/gal	Water	Low frill
Monuron; 2 lb; LF	Monuron	2.0 lbs/gal	Water	Low frill

[a] a.h.g. means acid equivalent per hundred gallons of solution.

The treated trees were examined at the end of each summer for 4 years. Differences in effectiveness of treatments were delineated by an analysis of variance and Keuls' sequential method of testing (Snedecor, 1956).

RELATIVE COSTS VARY FOR TREATMENTS

The cost of treating a tree of given size varied with the method of application and the chemicals used (Table 2). Big trees, of course, cost more to treat than small.

It took about six times as long to make a frill and apply the herbicide solution as to basal spray a tree of the same size. Because of the relatively low effectiveness of basal sprays, however, far more chemical and solvent were needed to get good results, particularly on large trees. Total cost of basal spraying exceeded that of frill application of the same solutions.

Of the treatments tested, the 12.5 lbs a.h.g. solution of 2, 4, 5-T in frills was the cheapest. The application of 2 pounds of monuron per gallon of water was the most expensive treatment costing more than 15 times as much as the cheapest treatment. Because the effectiveness of a given treatment was not always correlated with its cost, both effectiveness and cost should be considered in selecting a treatment for a given species.

RESULTS

Most trees, particularly large ones, did not die for several years after treatment. At the end of the fourth growing season, examination showed a complex relationship among species, size of tree, season of application, and the chemical concentration tested.

Table 2. Costs for materials used to treat trees varied by diameter classes.

(Cost per 100 trees)[a]

Treatment Code[b]	Tree diameter classes in inches					
	1	2-3	4-6	7-10	12	14
Ammate; 4 lb; LF	$0.19	$0.46	$0.93	$1.58	$2.23	$2.60
Ammate; 4 lb; HF	.19	.46	.93	1.58	2.23	2.60
2,4,5-T;12.5 lb; LF	.09	.23	.46	.78	1.10	1.28
2,4,5-T; 12.5 lb; BS	.46	1.15	2.30	3.90	5.52	6.44
2,4,5-T; 50 lb; LF	.25	.61	1.22	1.96	2.94	3.43
2,4,5-T; 50 lb; BS	1.22	3.06	6.12	10.40	14.70	17.15
Monuron; ½ lb; LF	.35	.88	1.75	2.98	4.20	4.90
Monuron; 2 lb; LF	1.40	3.50	7.00	11.90	16.80	19.60

[a]Based on following costs for materials:
Ammate at $0.20 per pound
2,4,5-T at $7.00 per gallon (4 pound acid equivalent)
Monuron at $3.00 per pound (80% active ingredients)
No. 1 fuel oil at $0.15 per gallon

[b]Treatment codes are explained in Table 1.

BEST TREATMENT AND SEASON VARIED WITH SPECIES

No single treatment was equally effective on all species in all months. The best month for application in frills differed from that for basal sprays. Both methods apparently had a girdling effect on the trees. The crowns themselves were relatively easy to kill, but the roots of some species were very resistant. In this study, a tree was classed as "killed" only when both the top and the roots were dead.

Kill of Both Tops and Roots Seldom Achieved

None of the chemicals tested killed all the trees under all conditions, but some treatments were far more effective than others. The susceptibility to herbicides varied greatly among species. Chemicals generally were applied near the base of the tree, and very little translocation was necessary to kill the crowns. These chemicals interfere with photosynthesis; if the herbicide reached the root system when its carbohydrate reserve was low, more kills resulted. Adequate translocation to kill the roots depended on the herbicide concentration, the point of application, and the stage of growth or dormancy of the individual tree.

2,4,5-T.—The most useful herbicide of those tested appears to be 2,4,5-T in mixture with fuel oil. When used in frills, the 50 lb a.h.g. solution was very effective in June, killing more than 80% of the trees of all species. Month and species were important; significantly more post oak died following February application (Table 3).

Table 3. Effectiveness of treatments by species and month of application. Data show per cent of trees 4-inch class or larger having both tops and root systems killed by "best" 6 treatments.

Treatment		Per cent	Treatment		Per cent
Code[a]	Month	kill[b]	Code	Month	kill
WHITE OAK			BLACK OAK		
2, 4, 5-T; 50 lb; LF	June	91	Monuron; 2 lb; LF	June	97
2, 4, 5-T; 50 lb; LF	Feb.	88	Monuron; 2 lb; LF	Feb.	97
Monuron; 2 lb; LF	June	80	Monuron; 2 lb; LF	Nov.	93
2, 4, 5-T; 12½ lb; LF	Nov.	80	2, 4, 5-T; 50 lb; LF	June	83
Ammate; 4 lb; LF	Nov.	80	2, 4, 5-T; 50 lb. BS	Feb.	76
Ammate; 4 lb; LF	Feb.	77	Ammate; 4 lb; LF	June	76
Ammate; 4 lb; HF	Nov.	67	2, 4, 5-T; 50 lb; LF	Feb.	76
2, 4, 5-T; 50 lb; LF	Nov.	67	2, 4, 5-T; 12½ lb; LF	June	73
Ammate; 4 lb; HF	June	67	Ammate; 4 lb; LF	Nov.	73
Ammate; 4 lb; HF	Feb.	67	2, 4, 5-T; 12½ lb; LF	Nov.	73
Monuron; 2 lb; LF	Nov.	67	Ammate; 4 lb; HF	June	56
Monuron; 2 lb; LF	Feb.	57	2, 4, 5-T; 50 lb; BS	June	56
2, 4, 5-T; 12½ lb; LF	June	57	2, 4, 5-T; 50 lb; LF	Nov.	56
2, 4, 5-T; 50 lb; BS	Nov.	57	2, 4, 5-T; 50 lb; BS	Nov.	56
2, 4, 5-T; 50 lb; BS	June	49	Ammate; 4 lb; LF	Feb.	56
Ammate; 4 lb; LF	June	49	Ammate; 4 lb; HF	Nov.	51
2, 4, 5-T; 50 lb; BS	Feb.	34	Ammate; 4 lb; HF	Feb.	42
2, 4, 5-T; 12½ lb; LF	Feb.	11	2, 4, 5-T; 12½ lb; LF	Feb.	30
BLACKJACK OAK			POST OAK		
Monuron; 2 lb; LF	June	98	Monuron; 2 lb; LF	June	99
2, 4, 5-T; 50 lb; BS	Feb.	89	2, 4, 5-T; 50 lb; LF	Feb.	92
Monuron; 2 lb; LF	Feb.	89	2, 4, 5-T; 12½ lb; LF	Nov.	90
Monuron; 2 lb; LF	Nov.	89	Monuron; 2 lb; LF	Nov.	87
2, 4, 5-T; 50 lb; LF	June	81	Ammate; 4 lb; LF	Nov.	82
2, 4, 5-T; 50 lb; BS	Nov.	79	Ammate; 4 lb; HF	Nov.	82
2, 4, 5-T; 12½ lb; BS	Feb.	79	Ammate; 4 lb; HF	June	82
Ammate; 4 lb; LF	June	79	2, 4, 5-T; 50 lb; LF	June	82
2, 4, 5-T; 50 lb; LF	Nov.	79	Monuron; 2 lb; LF	Feb.	82
Monuron; ½ lb; LF	June	75	2, 4, 5-T; 50 lb; BS	Nov.	75
Ammate; 4 lb; LF	Nov.	75	2, 4, 5-T; 12½ lb; LF	June	75
Ammate; 4 lb; LF	Feb.	75	Ammate; 4 lb; LF	Feb.	75
2, 4, 5-T; 12½ lb; BS	Nov.	60	Ammate; 4 lb; HF	Feb.	75
2, 4, 5-T; 50 lb; BS	June	60	2, 4, 5-T; 50 lb; LF	Nov.	75
Monuron; ½ lb; LF	Nov.	60	2, 4, 5-T; 50 lb; BS	June	68
2, 4, 5-T; 50 lb; LF	Feb.	40	2, 4, 5-T; 50 lb; BS	Feb.	68
Monuron; ½ lb; LF	Feb.	40	Ammate; 4 lb; LF	June	68
2, 4, 5-T; 12½ lb; BS	June	40	2, 4, 5-T; 12½ lb; LF	Feb.	15

[a] Treatment codes are described in Table 1.

[b] Each per cent kill shown differs significantly from those for adjacent treatment-month combinations or from groups of combinations giving statistically equal kills.

Increased concentrations of chemical did not always give better kills. When both the 50-pound and the 12.5-pound a.h.g. solutions of 2,4,5-T were applied in November, for example, the weaker solution killed far more post oaks than the stronger one. Apparently the high concentration caused enough local damage to the cells to reduce translocation of the herbicide the following spring. Yamaguchi and Crafts (1959) found that 2,4,5-T is consistently absorbed and translocated in the phloem and that little movement of this chemical occurs during the dormant season. In general, however, the less concentrated solution was least effective.

Basal spray treatments were relatively expensive and not very effective. The 12.5-pound a.h.g. solution killed very few trees as a basal spray, and the 50-pound a.h.g. solution was successful only on blackjack oak. Dormant-season applications killed 80 to 90% of this species, but the excessive amount of material required to wet the root collar increases the cost of the technique. Bramble (1953) and McQuilkin (1957) found that the root systems of the oaks were not killed by basal sprays unless the solution reached the root collar buds. Other treatments usually were both cheaper and better for eliminating the oaks.

Ammate.—The effectiveness of this chemical varied with both month of treatment and species. When applied in frills during the dormant season, 4 pounds of ammate per gallon of water killed more white and post oaks than black and blackjack oaks. In contrast, significantly higher mortality of the black oak group followed June application.

Applied in frills at waist height, ammate killed few black oaks at any time and was much less effective on white and blackjack oaks than when the frills were made close to the ground. However, height of the frills made very little difference in the per cent of post oak killed.

Although not as effective as the 50-pound a.h.g. solution of 2,4,5-T in frills, ammate costs less. Since this chemical is generally effective during the dormant season, there may be occasions when it will be more convenient to use then 2,4,5-T.

Monuron (CMU).—When applied in concentrations of 0.5 lb of 80% active chemical per gallon of water, monuron was among the least effective of the treatment tested. In contrast, the 2-lb concentration applied in June killed virtually all but the white oaks. The material is so costly at present, however, that its use probably cannot be warranted except in very unusual circumstances. These might include inaccessible places where effectiveness is more important than first cost.

Good Crown Kill Usually Possible

Where the primary objective of treatment is to kill the crowns of the oaks, as in releasing understory conifers, most of the herbicides are satisfactory. Chemicals applied in the dormant season usually killed the tops of nearly all trees. Both the season of treatment and point of frilling for best topkills were unlike those giving the best kills of both top and root systems.

2,4,5-T.—Although applications of 2,4,5-T in June usually killed more oaks than in other months, the best topkills followed February application of a 50 lb a.h.g. solution in frills (Table 4). In contrast, the 12.5 lb a.h.g. solution was nearly useless in February, but was about

Table 4. Five treatments giving best topkill of trees 4-inch class and larger by species and month of application.

Treatment		Per cent	Treatment		Per cent
Code[a]	Month	topkill[b]	Code	Month	topkill
WHITE OAK			BLACK OAK		
2,4,5-T; 50 lb; LF	Feb.	99	Monuron; 2 lb; LF	June	100
Ammate; 4 lb; HF	Feb.	93	Ammate; 4 lb; HF	Nov.	100
Ammate; 4 lb; HF	Nov.	93	2,4,5-T; 50 lb. LF	Feb.	100
2,4,5-T; 50 lb; LF	June	93	Ammate; 4 lb; HF	June	100
2,4,5-T; $12\frac{1}{2}$ lb; LF	Nov.	89	Ammate; 4 lb; LF	Nov.	95
Ammate; 4 lb; LF	Feb.	89	Monuron; 2 lb; LF	Feb.	95
Ammate; 4 lb; LF	Nov.	84	Monuron; 2 lb; LF	Nov.	95
Ammate; 4 lb; HF	June	79	Ammate; 4 lb; HF	Feb.	91
Monuron; 2 lb; LF	June	79	2,4,5-T; $12\frac{1}{2}$ lb; LF	Nov.	91
Monuron; 2 lb; LF	Nov.	66	2,4,5-T; 50 lb. LF	June	91
2,4,5-T; 50 lb; LF	Nov.	73	Ammate; 4 lb; LF	June	86
Monuron; 2 lb; LF	Feb.	58	2,4,5-T; $12\frac{1}{2}$; LF	June	86
Ammate; 4 lb; LF	June	58	Ammate; 4 lb; LF	Feb.	81
2,4,5-T; $12\frac{1}{2}$ lb; LF	June	58	2,4,5-T; 50 lb; LF	Nov.	79
2,4,5-T; $12\frac{1}{2}$ lb; LF	Feb.	11	Ammate; 4 lb; LF	Feb.	32
BLACKJACK OAK			POST OAK		
Ammate; 4 lb; LF	Feb.	99	Ammate; 4 lb; HF	Nov.	98
Ammate; 4 lb; LF	June	99	2,4,5-T; 50 lb; LF	Feb.	98
Ammate; 4 lb; LF	Nov.	99	Monuron; 2 lb; LF	June	98
Ammate; 4 lb; HF	Feb.	99	Ammate; 4 lb; HF	Feb.	94
Ammate; 4 lb; HF	June	99	Ammate; 4 lb; LF	Nov.	94
Ammate; 4 lb; HF	Nov.	99	2,4,5-T; $12\frac{1}{2}$ lb; LF	Nov.	94
2,4,5-T; 50 lb; LF	Feb.	99	Ammate; 4 lb; LF	Feb.	87
Monuron; 2 lb; LF	Feb.	99	Ammate; 4 lb; HF	June	87
Monuron; 2 lb; LF	June	99	2,4,5-T; 50 lb; LF	June	87
2,4,5-T; $12\frac{1}{2}$ lb; LF	June	96	Monuron; 2 lb; LF	Nov.	87
2,4,5-T; $12\frac{1}{2}$ lb; LF	Nov.	96	2,4,5-T; $12\frac{1}{2}$ lb; LF	June	81
2,4,5-T; 50 lb; LF	June	96	Monuron; 2 lb; LF	Feb.	81
Monuron; 2 lb; LF	Nov.	96	Ammate; 4 lb; LF	June	71
2,4,5-T; 50 lb; LF	Nov.	89	2,4,5-T; 50 lb; LF	Nov.	71
2,4,5-T; $12\frac{1}{2}$ lb; LF	Feb.	52	2,4,5-T; $12\frac{1}{2}$ lb; LF	Feb.	11

[a] Treatment codes are described in Table 1.

[b] Each per cent kill shown differs significantly from those for adjacent treatment-month combinations or from groups of combinations giving statistically equal kills.

as effective in November as the much more expensive 50 lb a.h.g. concentration. The cheaper treatment killed the crowns on 90% or more of the oaks. The basal spray treatments of 2, 4, 5-T were effective only on the small trees. The relatively high cost for materials probably will limit use of this method.

Ammate. —With the exception of large white oaks, dormant-season applications of ammate killed the crowns of nearly all oaks regardless of size. Better top kills resulted from ammate application in waist high frills, but more basal sprouting followed than when the frills were made close to the ground.

Monuron. —Generally, monuron either killed the trees outright or did very little damage to the crown. June application of the 2 lb solution gave consistently good topkills of all species except white oak. Other chemicals are about as effective and much cheaper to use on this species.

TOP AND ROOT KILLS BOTH RELATED TO TREE SIZE

The treatments tested were most effective on trees of a limited range in size classes, indicating the need for matching treatment to the size of trees. In general, the bigger the tree, the more difficult it was to kill either the tops or both tops and roots.

No Treatment Killed All Trees of All Sizes

The basal sprays were effective only on small trees. Chemicals applied to fresh-cut surfaces killed fewer large than small trees, with the exceptions of 2, 4, 5-T and monuron at the 2 lb rate (Table 5). Month of treatment and size of tree also were interrelated.

2, 4, 5-T. —This chemical used in frills usually was more effective on small than on large trees; however, the 50 lb a.h.g. solution applied in February killed more large then small trees, and more trees 11 inches and larger than most other treatments. The 12.5 lb a.h.g. solution showed a similar trend in effectiveness when used in November. Accumulation of 2, 4, 5-T in the phloem during the dormant season apparently caused less local cell damage in large than in small trees, with a subsequent increase in translocation and mortality for the large trees.

Basal sprays of the 50 lb a.h.g. solution successfully eliminated 1- to 3-inch black, blackjack, and post oaks. Dormant-season application usually was best. The 12.5 lb a.h.g. solution killed few trees larger than 2 inches.

Ammate. —Sprouts and trees less than 3 inches in diameter were killed most easily and cheaply with dormant season applications of ammate to freshly-cut surfaces. On larger trees, however, the number of trees killed decreased rapidly with tree size.

Monuron. —This chemical usually was more effective in killing small than large trees, but more large than small black oaks were killed when a 2 lb/gal solution of monuron was applied in frills regardless of month. Although black oak was killed more easily than the other species by monuron, there seems to be no obvious reason why the larger trees were most susceptible. Similarly, no explanation is offered for a better kill of large post oaks by treatment in June.

Table 5. The per cent of trees killed in each species and diameter group by the 10 most effective combinations of chemical and month of application.

(In per cent)

Treatment		Tree diameter in inches			Weighted
Code	Month	1-3	4-10	11+	mean
WHITE OAK					
2,4,5-T; 50 lb; LF	June	95%	95%	84%	93%
Ammate; 4 lb; LF	Nov.	100	85	72	88
Ammate; 4 lb; LF	Feb.	100	83	67	87
Monuron; 2 lb; LF	June	92	93	50	84
2,4,5-T; 50 lb; LF	Feb.	66	85	93	79
2,4,5-T; $12\frac{1}{2}$ lb; LF	Nov.	58	78	80	70
2,4,5-T; 50 lb; LF	Nov.	62	78	47	65
2,4,5-T; $12\frac{1}{2}$ lb; LF	June	74	68	34	63
Monuron; 2 lb; LF	Nov.	60	80	37	63
Ammate; 4 lb; LF	June	78	70	6	61
POST OAK					
Monuron; 2 lb; LF	June	88%	98%	100%	95%
Ammate; 4 lb; LF	Nov.	98	83	85	90
Monuron; 2 lb; LF	Nov.	88	92	78	87
2,4,5-T; 50 lb; LF	June	92	87	76	86
2,4,5-T; $12\frac{1}{2}$ lb; LF	Nov.	79	89	90	85
2,4,5-T; 50 lb; BS	Nov.	94	85	67	85
2,4,5-T; 50 lb; LF	Feb.	72	90	97	84
Ammate; 4 lb; LF	Feb.	95	75	78	84
2,4,5-T; $12\frac{1}{2}$ lb; LF	June	90	80	71	82
Monuron; 2 lb; LF	Feb.	83	85	68	81
BLACK OAK					
Monuron; 2 lb; LF	June	93%	97%	100%	96%
2,4,5-T; 50 lb; LF	June	94	87	77	88
Monuron; 2 lb; LF	Feb.	72	100	86	86
Ammate; 4 lb; LF	Nov.	95	78	73	83
2,4,5-T; 50 lb; BS	Feb.	94	91	40	82
Monuron; 2 lb; LF	Nov.	63	95	90	81
Ammate; 4 lb; LF	June	87	72	70	80
2,4,5-T; $12\frac{1}{2}$ lb; LF	June	80	82	53	75
Ammate; 4 lb; LF	Feb.	93	52	67	71
2,4,5-T; 50 lb; BS	Nov.	93	71	28	71
BLACKJACK OAK					
2,4,5-T; 50 lb; BS	Feb.	95%	95%	(No data)	95%
Monuron; 2 lb; LF	June	90	98		95
Ammate; 4 lb; LF	June	90	78		84
Ammate; 4 lb; LF	Feb.	93	73		83
Monuron; 2 lb; LF	Feb.	70	94		82
Ammate; 4 lb; LF	Nov.	92	72		82
2,4,5-T; 50 lb; BS	Nov.	83	78		81
2,4,5-T; 50 lb; LF	June	80	81		81
Monuron; 2 lb; LF	Nov.	66	93		80
2,4,5-T; $12\frac{1}{2}$ lb; BS	Feb.	76	77		77

Crown Kill Decreased with Tree Size

June application of the 2 lb/gal solution of monuron killed the tops of all post and black oaks. With this exception, no treatment killed the crowns of all trees 11 inches and larger. The per cent of topkilled trees generally decreased as tree size increased. Because of the relative ease with which the crowns can be killed, however, this decrease is not too significant.

OTHER FACTORS ALSO INFLUENCE TREATMENT CHOICE

The best treatment and season of application in a given instance depends not only on the species and size of trees to be eliminated, but on the objectives of the landowner. Land clearing costs more than plantation release because the latter often may be accomplished without killing all the oak overstory. Where kill of all the oaks is required, the choice of treatments and seasons will be limited; either costly materials must be used or a less effective but cheaper treatment must be applied more often.

The cost of labor may also affect choice of treatment. If all labor must be hired, the prudent landowner obviously will select the best combination of season and treatment to do the job. Farmers often have free time during the winter. So it may be more practicable for them to use a dormant-season treatment that is less effective than some other treatment requiring application when they are working in the fields. For example, a 50 lb a.h.g. solution of 2, 4, 5-T in frills kills all the oaks (except blackjack) about as well in February as in June.

Further savings are possible to the man doing his own work: materials to treat 100 5-inch trees cost only $0.46 where the 12.5 lb a.h.g. solution of 2, 4, 5-T is used, as compared with $1.22 for the 50 lb a.h.g. solution. Using the cheaper treatment in November probably would kill within 10% as many trees as the 50 lb a.h.g. concentration. A follow-up treatment generally is necessary in either case to kill all trees.

SUMMARY

White, black, post, and blackjack oaks can be controlled with chemicals applied by hand methods. A study compared the effectiveness of 8 chemical-mechanical treatments for killing oak trees of 5 diameter classes and 4 species. More than 14, 000 numbered trees were used to test several concentrations of 2, 4, 5-T, ammate, and monuron applied by several methods in 3 different months.

Four years after treatment, a complex relationship was found between species, size of tree, month of application, and concentration of the chemicals. Of those tested, no single treatment-month combination consistently gave the best kills of all sizes and all species. Except on white oak, a 2 lb/gal solution of monuron applied in frills in June was more effective than any other treatment. November application of the 12.5 lb a.h.g. solution of 2, 4, 5-T in frills killed as many white oaks as monuron applied in June, but February applications killed very few trees

of any species. June application of the 50 lb a.h.g. solution of 2,4,5-T killed more than 80% of all trees treated. Ammate killed more white and post oaks when used during the dormant season, but June treatments were best on black and blackjack oaks.

Small trees usually were easier to kill than large ones. Good crown kills generally followed dormant season applications, but the best kills of the root systems were obtained with June treatments.

Chemical costs differed greatly among treatments; the most expensive treatment cost 15 times as much as the cheapest and was not always more effective. Even though basal sprays required only one-sixth as much time to apply as frill treatments, the chemicals used cost about 5 times as much, and this expense far exceeded that for labor. Thus, basal sprays not only were less effective than frills, they also cost more.

The best treatment and month combination to use in a particular case depends on (1) the objectives of the landowner; (2) the species and size of trees to be treated; and (3) the cost of labor at various seasons of the year.

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ABNORMAL FLOWERING BEHAVIOR IN ASPEN

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INTRODUCTION

Aspen, once considered a weed tree, is becoming increasingly important in forest economy in the Lake States. Bigtooth aspen (Populus grandidentata Michx.) and quaking aspen (P. tremuloides Michx.) are the two species of Populus native to the Lake States area that are commonly referred to as "popple." Both species are dioecious and aspen stands are commonly composed of intermingled clones of staminate and pistillate trees. Although most aspen stands are of sprout origin, studies dealing with the genetic improvement of these two species have increased the interest of research workers in the flowering behavior of aspen.

Flowers of aspen, as shown in Figure 1, develop from the large buds located just below the terminal bud. Flower buds are normally concentrated in the upper part of the crown and on fully exposed branches in the lower positions. The sex of a tree can be determined by field examination of the flower buds with a hand lens as early as December.

The flowers of aspen, like other members of the genus Populus, are borne in aments or catkins. Normally, staminate and pistillate catkins of quaking aspen elongate and pollination in northern Wisconsin occurs during the last week of April. Following pollination, the pistillate catkins develop rapidly and the dehiscences of the capsules and the release of the seed with the attached cotton begins after 18 to 21 days.

Flowering of bigtooth aspen follows a similar pattern with elongation and pollination occurring 10 to 12 days later than in quaking aspen. Bigtooth and quaking aspen can be crossed with ease in the greenhouse and it appears that the difference in time of flowering is the principal reason for lack of natural hybridization between these two species.

The method used in forcing aspen to flower is the technique commonly employed in Sweden and other European countries and is known as the "cut branch technique." This technique involves collecting branches with flower buds in late January and forcing them in the greenhouse at a temperature of 65°F. Water in the vases is changed daily and each day a small section of wood is clipped from the end of the branches to prevent bacterial plugging of the stem. As the staminate catkins elongate, they are collected in small boxes and the pollen is extracted by shaking the dry catkins over a standard 40-mesh screen and collecting the pollen on a paper placed below the screen. The female catkins are pollinated by applying the pollen with a small camel's-hair brush.

[1] The author is indebted to Dr. Philip N. Joranson, Dr. J. P. van Buijtenen, and Fred Sweeney for assistance in manuscript preparation and photographic work.

Figure 1. The above three staminate flower buds and the single vegetative bud (upper right) illustrate the relative size and location of flower buds in quaking aspen.

The Institute of Paper Chemistry's project on the genetic improvement of aspen has involved the forcing and crossing of a large number of specimens of bigtooth and quaking aspen. During the course of the handling of this material a number of interesting abnormalities have been observed and are herein reported.

BRANCHED STAMINATE CATKINS

One interesting feature noticed in several staminate clones of quaking aspen is the branching of the catkins. Normally, the staminate catkins consist of a single stem from which arise a number of scale-like appendages. These appendages have the outer edges curled and inside these edges and resting on the scales are located the anthers. As Figure 2 clearly illustrates, when branching occurs the main portion of the catkin is quite normal except for the existence of a number of small flattened catkins which are attached to the main catkin near the base. The number of small catkins varies from three to eight. Pollen production of the clones having branched catkins was quite normal and germination was satisfactory. The principal value of such an abnormality exists in its usefulness as a genetic marker in breeding experiments.

Figure 2. Normal and branched staminate catkins in which the bud scales and cottony attachments have been removed. Note the small flattened catkins attached to the main catkin near the base.

HERMAPHRODITISM IN ASPEN

Another interesting and potentially useful abnormality observed in several clones of quaking aspen is the presence of both staminate and pistillate flowers on the same tree. Location of the two types of flowers varies within a clone and from one clone to another. One clone of quaking aspen from Lower Michigan had catkins which were either predominantly staminate or pistillate with only a few scattered flowers of the opposite sex. Observations on a second clone revealed pistillate flowers in one part of the catkin and staminate flowers in another. Figure 3 illustrates a third type of hermaphroditism in which the two types of flowers are located together in a single flower.

Hermaphroditism in the genus Populus has been widely reported. Hastings (1918), Erlanson and Hermann (1927), Peto (1938), Seitz (1953), Schlenker (1955), Pauley and Mennel (1957), and May (1959) each described discoveries and studies of hermaphroditism in the genus Populus. Recent investigations by Santamour (1955) and Pauley and Mennel (1957) indicated hermaphroditism in Populus, particularly P. tremuloides, may be more common than formerly believed. Results of this work at the Cabot Foundation and the University of Minnesota suggest that the incidence of hermaphroditism in the wild quaking aspen population may run as high as 4 to 5% among males and 10 to 20% among females.

Figure 3. A hermaphroditic flower of quaking aspen with staminate portion above and pistillate portion below.

Seitz's work (1954) in which he produced 19 triploids ouf of a total of 2,000 seedlings by self-pollination of a hermaphroditic gray poplar points up one possible important use for material of this nature. Another possible use is for the establishment of inbred lines that can be used in hybridization work.

LATE FLOWERING IN ASPEN

During the 1956, 1957, 1958, and 1959 breeding season late-flowering catkins were observed on a number of branch collections being forced in the greenhouse. Usually, eight to ten days after producing a number of catkins at the normal time, other flower buds elongated and produced a second crop of catkins on the same branches. "Late-flowering" as here described was observed on five female clones and one male clone of quaking aspen and on one female clone of bigtooth aspen. In some clones this behavior might properly be called "two-phase" flowering but in other instances a distinct separation between successive crops of flowers is lacking.

In two of the observed cases of late-flowering the catkins were partly flower-bearing and partly vegetative. Figure 4 pictures a staminate late-flowering catkin from one of the clones and Figure 5 illustrates a typical late-flowering pistillate catkin from another clone. The proximal portions of the catkin of these two clones were flower-bearing while the

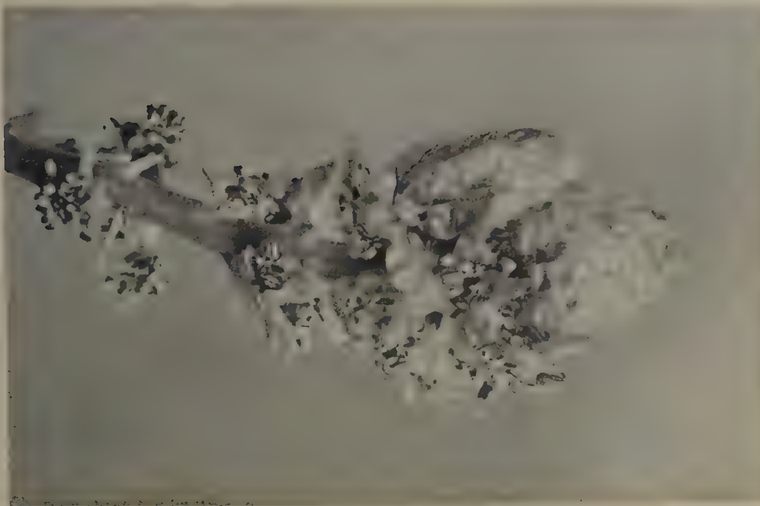

Figure 4. A late-flowering staminate catkin of quaking aspen with vegetative development in the distal portion.

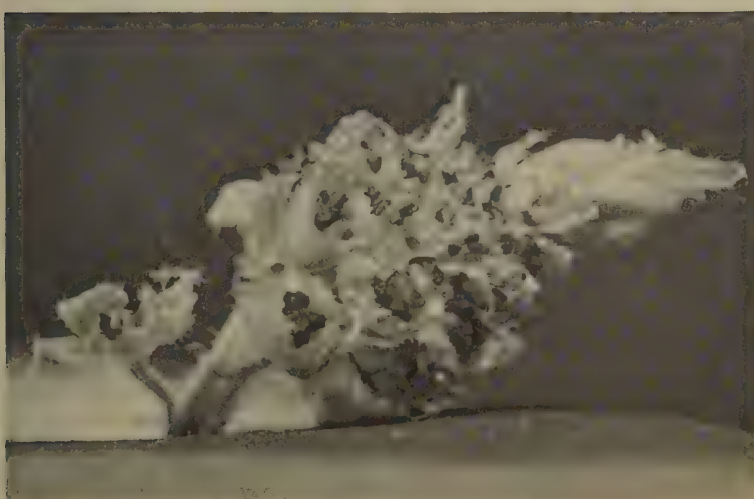

Figure 5. A late-flowering, pistillate catkin of quaking aspen with long-pediceled individual flowers. Note the petal-like bracts of individual flowers and the distal vegetative portion.

Figure 6. First-appearing (left) and late-flowering (right), female catkins of quaking aspen. The late-flowering catkins are in anthesis; the catkins at left flowered 10 days earlier.

distal portion was made up of numerous, crowded bractlike or leaflike appendages. The individual flowers of the pistillate catkins shown in Figure 5 were not short-stalked, as is commonly the case, but were attached to the rachis by rather longer pedicels. Each individual flower was also subtended by good-sized bracts, giving it a more flowerlike appearance.

Another interesting aspect of late-flowering is illustrated in Figure 6. This flower-bearing material from a female quaking aspen produced about 60% normal-flowering catkins, which when pollinated artificially, resulted in a good seed set. Five to six days after pollination and as the first set of catkins was showing evidence of seed development, additional catkins began to elongate. Beginning ten days after pollination of the first-appearing catkins, a total of 100 receptive late-flowering catkins was removed from this branch collection.

The occurrence of late-flowering in aspen, described in greater detail in an earlier paper (Einspahr and Joranson, 1960) has certain important genetic implications. These implications are related to the occurrence of natural hybridization between bigtooth and quaking aspen. Recent reports of naturally occurring hybrids between species in the genus Populus have been made by McComb and Hansen (1954), Pauley (1956), Joranson (1957), Langenbach (1957), and Heimburger (1958). Quaking and bigtooth aspen are often found growing side by side but hybridization

does not commonly take place apparently because of the difference in the time of flowering. Pauley (1956) suggests that quaking aspen growing in localities in which spring temperature inversion was common might flower late enough to permit natural hybridization with nearby bigtooth aspen growing on higher ground, and found hybrids in a location where temperature relations of this sort evidently existed. The occurrence of late-flowering catkins in quaking aspen suggest another method by which this time difference might be bridged.

SUMMARY

Bigtooth and quaking aspen stands in the Lake States are made up of intermingled clones of male and female trees. Tree improvement work with aspen has resulted in increased interest in the flowering behavior of aspen, with the result that a number of trees exhibiting flowering abnormalities have been located. Branched staminate catkins in quaking aspen, hermaphroditism in quaking aspen, and late-flowering in bigtooth and quaking aspen are the abnormalities pictured and described.

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SOME FACTORS AFFECTING OAK AND BLACK WALNUT REPRODUCTION

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Oak and black walnut trees in Iowa frequently produce seed in abundance, yet seedlings are scarce. Why is this? An earlier exploratory study[1] showed that virtually all acorns were taken by rodents regardless of whether the acorns were on top of the litter, on the soil under the litter, or in the soil under the litter. At the same time new oak seedlings were observed on nearby areas which were free of litter, suggesting a relation between amount of oak reproduction and amount of litter.

In 1955 a study was begun in an even-aged oak stand of moderate density on the Amana Experimental Forest in Iowa to further test the effects of litter, screening, and sowing-versus-planting on the production of oak and black walnut seedlings. The results show that all these things are important for the establishment of oaks from seed, but only screening and seed placement affect black walnut seedling establishment, at least on areas similar to the study area.

EXPERIMENTAL PROCEDURE

Seeds were sowed or planted on 24 3 x 11 ft plots located at least 20 feet apart on a north slope, a south slope, and a ridge. All plots were free of tree reproduction and brush. Four species of oak—black (Quercus velutina Lam.), bur (Q. macrocarpa subsp. olivaeformis Michx. f.), white (Q. alba L.), and northern red (Q. rubra L.)—and black walnut (Juglans nigra L.) were used.

Litter was removed from 12 of the plots and from a 3 ft strip around each of them. On 6 of these plots seeds were placed on top of the mineral soil, and on the other half seeds were planted an inch deep in the soil.

Litter was left in place on the other 12 plots. In 6 of these, seeds were planted an inch deep in mineral soil with minimum disturbance to the litter. In the other six, seeds were placed on top of the litter.

In all plots 40 seeds of each species were sowed or planted—a total of 4,800 seeds. Three plots in each treatment (a total of 12) were covered with hardware cloth to exclude rodents. These exclosures were constructed with the edges buried and the top about a foot above ground.

Except for white oak, seeds were sowed or planted in the plots shortly after being collected. The white oak acorns matured earlier than the other species and were collected and kept in cold storage for 2 weeks before they were used.

[1]Krajicek, John E. 1955. Rodents influence red oak regeneration. Central States For. Exp. Sta. Note No. 91. 2 pp.

The black walnut seeds planted in the soil were hulled, but those placed on the litter and on the soil surface were not. This was done to simulate what occurs in nature: Walnuts buried by squirrels are usually hulled, while those left on the ground usually retain their hulls over winter.

RESULTS AND DISCUSSION

Oaks

The most oak seedlings were established where the litter was removed, the acorns were planted in the soil, and protected by screening. Planting the acorns in the soil was better than sowing them on the surface of either the litter or mineral soil (Table 1). Neither litter removal nor screening affected oak seedling production from acorns sowed on the surface. For acorns planted in the soil, however, the effects of screening and litter removal were highly significant (at the one per cent level).

The absence of litter had little effect on the number of seedlings produced when the seed was sowed on the surface, but the removal of litter where acorns were planted in the soil increased the number of seedlings by nearly two and one-half times on the screened plots and by three times on the unprotected plots. While these results do not support the conclusion of earlier investigations,[2] that litter is beneficial or at least not detrimental for acorn germination, they were consistent among aspects and species.

Two factors apparently accounted for the difference in numbers of seedlings when litter was present and acorns were planted in the soil compared to plots where litter was removed. In the first place, acorn losses were slightly higher on the plots where the litter was intact. Secondly, and of greater importance, was the difference between the number of acorns that started to germinate and the number of seedlings produced. Where litter was present only 43 per cent of the acorns that started to germinate produced seedlings. However, where litter was absent, 83 per cent of the acorns which germinated did produce seedlings. Several common soil-inhabiting fungi (capable of producing damping-off) and sap-and-fungus-feeding beetles (family Nitidulidae) were found associated with acorns which began germination but did not produce seedlings.[3] Differences in the per cent of germinating acorns producing seedlings were not affected by screening.

One unprotected plot, from which litter has been removed and the acorns planted in the soil, had a light layer of leaves blown on a small portion of it in early spring. On that plot 14.4 per cent of the acorns

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[2]Barrett, L.I. 1931. Influence of forest litter on the germination and early survival of chestnut oak, Quercus montana, Willd. Ecol. 12: 476-484.

Korstian, C.F. 1927. Factors controlling germination and early survival in oaks. Yale University School of Forestry. Bul. No. 19. 115 pp., illus.

[3]Identification of fungi and insects was made by Dr. Harold S. McNabb, Department of Botany, Iowa State University of Science and Technology, Ames.

Table 1. Percentage of oak and black walnut seedlings established, missing seeds and other failures by treatment.

Treatments			Seedlings present (%)	Seeds missing[1] (%)	Seeds present but no seedling (%)
OAK					
Seeded on surface	Screened	Litter intact	0.0	2.5	97.5
		Litter removed	4.6	0.0	95.4
	Not screened	Litter intact	0.2	99.8	0.0
		Litter removed	0.0	100.0	0.0
Planted in soil	Screened	Litter intact	25.2	17.5	57.3
		Litter removed	61.5	16.2	22.3
	Not screened	Litter intact	15.4	56.5	28.1
		Litter removed	46.7	41.0	12.3
BLACK WALNUT					
Seeded on surface	Screened	Litter intact	0.0	0.0	100.0
		Litter removed	0.0	0.0	100.0
	Not screened	Litter intact	0.0	100.0	0.0
		Litter removed	0.0	100.0	0.0
Planted in soil	Screened	Litter intact	57.5	10.8	31.7
		Litter removed	68.3	5.1	26.6
	Not screened	Litter intact	1.7	97.5	0.8
		Litter removed	0.0	100.0	0.0

[1] Some of the missing seeds were probably present but could not be located. There also was evidence of a small amount of pilferage by rodents on the screened plots.

planted had incomplete germination, compared to 6.2 per cent for two other plots receiving the same basic treatments but which remained bare of leaves. Thus, apparently damping-off also is an important factor in oak seedling production when only a thin layer of litter is present.

These results indicate that, for similar areas and with an adequate supply of acorns, the most important factor affecting seedling establishment is seed placement: the acorn must be in mineral soil. The second most important factor is litter, the presence of which inhibited germination and seedling establishment. The fact that litter-free plots contained 85 per cent more seedlings than the screened plots where litter was intact shows the absence of litter to be more important than protection from rodents.

Black Walnut

The results on seed placement were conclusive. None of the walnuts placed on the litter or on mineral soil produced seedlings. Of the nuts planted in the soil, up to 68 per cent produced seedlings (Table 1).

Unlike the acorns, screening greatly affected walnut seedling production. Virtually the only place seedlings were produced was in the screened plots. All of the nuts in unscreened plots disappeared within two days. It should be pointed out that black walnut was not a component of the stands in which the study was conducted. With natural supplies of walnuts available, lossess on the plots might have been different.

The effect of litter on walnut seedling production was not significant statistically. No incomplete germination was found for walnuts.

Differences between north slope, south slope and ridge were not significant statistically for any of the treatments.

SUMMARY

A study was begun on the Amana Experimental Forest in 1955 to test the effects of screening, litter, and seed placement on oak and black walnut germination under even-aged oak stands. As expected, seed placement strongly influenced seedling production. Litter was not detrimental to black walnut germination, but, contrary to general belief, the results have showed adverse effects of litter on acorn germination. Seed losses without screening were complete for black walnut, but were less important than seed placement and litter for the oaks. Differences among aspects and among the four oak species tested were not significant.

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FOREST ENCROACHMENT IN NATIVE PRAIRIE

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INTRODUCTION

This study was conducted to determine the extent of tree invasion in a tract of native bluestem prairie in east-central Missouri. The study site, consisting of 160 acres, was the Tucker Prairie Research Station acquired in 1956 by the University of Missouri.[1] It was never broken by the plow, and prior to acquisition was in the same family ownership for over 100 years. The tract is a characteristic example of the poorly-drained prairies which formerly occupied extensive areas in the glaciated section of the Middle West. The Prairie-type soils of the region are slowly permeable with a claypan subsoil, particularly on terrain where the pattern of natural surface drainage is least developed. In this region a forest climate is characteristic, in which the mean annual rainfall is approximately 40 inches. Physiographically, the study area lies in a broad tension zone between the forested breaks toward the south, and the flat prairie-lands of the drift region. Locally, elm and oak intrusions occur in the drainages and on eroded slopes. At the study site, one such forest intrusion is present in the drainage which borders the west boundary of the tract. Due to a noticeable encroachment of woody plants in the prairie within the past several years, a survey of invading species according to age and density was made in 1959. The composition of the border forest was also analyzed. These data provide a basis of comparing any future floristic and vegetational changes. In addition, the spatial relationship of young trees in the prairie and the parent forest at the edge may be evaluated. Prior to its acquisition as a scientific preserve, the tract was mowed more or less regularly, thus effecting a practical control of forest growth. Currently, a burning schedule is being initiated on selected areas within the invasion zone, to determine the effects of fire on woody vegetation. Thus, the present survey discussed in this paper is also a point of reference for future assessments of tree growth and competition in burned and unburned prairie.

PROCEDURES

The prairie tract is a square, one-half mile in length on each side. Total acreage of the forest along the west boundary as determined from aerial photographs was approximately 5.5 acres. This area was sampled intensively, with the assistance of a plant ecology class, in which

[1] Purchased with funds from the National Science Foundation, grant G-3724, Missouri Alumni Achievement Association, Missouri Chapter of Nature Conservancy, and private donations.

36 1/40 A plots (10 x 10 m) were analyzed. Density counts were determined for specimens 4.0 inches dbh and larger in these plots. For sizes 1-3.9 inches dbh, a 1/1000 A plot (2 x 2 m) was located in the southeast and northwest corners of the 10 x 10 m sampling area. Smaller sizes, nine-tenths inch in diameter and less, were counted in 1/4 milacre plots (1 x 1 m), located in the four corners of the previously located large plot. For additional data, one transect was run employing the quarter method (Cottam and Curtis, 1956). Twenty points were examined for a total of 80 trees, 4.0 inches dbh and larger. The densities of species in the invasion zone were determined using a 1/160 A plot size (5 x 5 m). These plots were spaced at 100-foot intervals along 3 east-west transect lines which extended approximately 1500 feet from the forested border. Beyond this point no evidence of active invasion was noted. A total of 45 plots was analyzed, 15 on each transect. Field data were averaged and expressed as densities per acre.

COMPOSITION OF THE BORDER FOREST

Species densities by diameter classes for the forest stand bordering the prairie are presented in Table 1. The principal species are shagbark hickory, Carya ovata; shingle oak, Quercus imbricaria; and American elm, Ulmus americana. An examination of the field data in relation to the disposition of plots, and quadrats along the transect, indicated a conspicuous division in species composition. The more developed forest was predominantly an oak and hickory type, concentrated in the lower portion of the drainage pattern bordering the prairie. Above this, in the less dissected part, the forest structure was simpler, and consisted primarily of American elm. Red elm, U. rubra, was restricted to the lower drainage. Of the principal species, shagbark hickory was most numerous, followed by shingle oak. High densities for these species were due primarily to the large number of specimens less than 1 inch in diameter. By comparison, elm was less numerous in this class, but was relatively more important in larger sizes. It was considerably more numerous than either species in the 4-9.9 inch class, and also exceeded shingle oak in the 1-3.9 inch range. The greater densities of elm in the mid-classes suggest that this relatively intolerant species has reached its successional peak. In the future development of the stand, the dominance of oak and hickory species should become more indicative. Lesser species of oak are also included in Table 1. The largest specimen was a swamp white oak, Q. bicolor, which measured 37 inches, dbh. Pin oak, Q. palustris, was not recorded, although in general it is a common species of the prairie region in mid-Missouri.

The average age of American elm measuring slightly less than 1 inch in diameter was 5.5 years. For other specimens measuring approximately 2.5, 6, and 15 inches, the ages determined were 13.7, 21.0, and 33.6 years respectively. The ages of shingle oak for generally similar sizes were 6.5, 14.0, 24.4, and 36.0 years. Shingle oak averaged somewhat older than elm in the larger classes. However, the representation of the latter in sizes exceeding 20 inches, and the absence of the oak in equivalent diameters, suggests that the elm is probably the older species in the drainage.

Table 1. Calculated species densities per acre in the border forest, by size classes (dbh), 1959.

Species	Less than 1 inch	1-3.9 inches	4-9.9 inches	10-19.9 inches	20 in. and over	Total
Carya ovata	722	500	23	27	0	1272
Quercus imbricaria	500	194	31	10	0	735
Q. alba	0	8	0	0	8	16
Q. bicolor	0	0	0	0	4	4
Q. velutina	0	0	3	0	0	3
Ulmus americana	111	306	131	28	8	584
U. rubra	0	28	23	4	0	55
Prunus serotina	0	0	23	0	0	23
Maclura pomifera	0	0	8	4	0	12
Gleditsia triacanthos	0	0	3	8	0	11
Prunus americana[1]						
Crataegus mollis[1]						
Pyrus ioensis[1]						
Rhus glabra[1]						
Juniperus virginiana[1]						

[1] Small trees or shrubs at the forest edge, outside sample plots.

TREE SPECIES INVADING THE PRAIRIE

The average densities of tree species in the prairie, based on the three transects, are presented in Table 2. In general, all specimens were less than 1 inch in diameter. American elm was the most abundant species. No other species showed abnormally high densities under present conditions. The greatest concentration of elm occurred inside the 250 foot zone bordering the forest. With increasing distance from the seed source, elm densities generally decreased, the greatest drop occurring between the second and third stations. Beyond approximately 1300 feet, no specimens of elm were recorded. Shingle oak was the only oak species in the prairie. It was limited to a fringe area bordering the forest proper, and did not occur in any of the transects beyond the first station.

The widespread occurrence of elm in the invasion zone compared to oak may be attributed to several factors. There is a greater abundance of seed which is produced relatively early in the season when conditions are normally favorable for germination and seedling establishment. Another factor favoring elm is the light weight of the disseminules, thus facilitating greater dispersal. Additional study is required to determine a more exact relationship between the spread of elm seed and distance from the parent tree. Utilization of acorns by rodents may also be a contributing influence in reducing oak establishment.

Table 2. Calculated species densities per acre in the invasion zone of the prairie, with increasing distance from the boundary forest. All specimens less than 1 inch in diameter at ground level. 1959.

Distance (Ft.)	Invading Species						Total
	Ulmus americana	Crataegus mollis	Pyrus ioensis	Prunus americana	Quercus imbricaria	Juniperus virginiana	
100	3680	0	0	0	160	0	3840
200	3360	0	0	0	0	0	3360
300	1120	0	0	0	0	0	1120
400	960	320	160	0	0	0	1440
500	960	0	0	0	0	0	960
600	640	160	0	0	0	0	800
700	320	0	160	160	0	0	640
800	480	0	0	0	0	0	480
900	320	0	0	0	0	160	480
1000	640	0	0	0	0	0	640
1100	160	0	0	160	0	0	320
1200	160	0	0	0	0	0	160
1300	160	0	0	0	0	0	160
1400	0	0	0	0	0	0	0
1500	0	0	0	0	0	160	160

Maclura pomifera observed outside plots.

The high densities of small elm trees in the invasion zone compared to the much smaller numbers within the forest itself indicate more suitable conditions in the prairie environment. Height measurements of elm varied from 12 to 108 inches. Some specimens were first year seedlings; none were older than five years determined approximately six inches above ground. Some specimens, however, were cut off by previous mowing and thus were somewhat older below the zone of regeneration. The rapid upsurge of elm growth in the past several years in the absence of disturbance factors such as mowing and burning suggests that absolute protection is detrimental to prairie vegetation in this region. The stability of prairie under primeval conditions favorable to forests would indicate that, in addition to geological and edaphic influences, fire was probably an important ecological factor in arresting tree invasion and maintaining vegetational equilibrium.

SUMMARY

1. A survey was made to determine the extent of forest encroachment in a native prairie in east-central Missouri.

2. American elm was the only important, but abundant, invading species. Densities were in inverse proportion to the distance from the bordering forest.

3. Although oak and hickory were also present in the adjacent forest stand, the extent of invasion was limited to a narrow fringe area.

4. The absence of any arresting influences such as mowing or burning is detrimental to stability of the prairie in a humid climate, where forest is generally common, as in east-central Missouri.

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MOISTURE SAMPLING IN WILDLAND SOILS WITH A NEUTRON PROBE

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Radioactivity has become a household word since the days of Hiroshima. The dangers of radiation are widely discussed. Less well known are the human benefits possible through the use of radioactive elements in research. One such technique, the measurement of soil moisture with a neutron probe, is already providing data important in understanding the soil-plant-water relations of wildland areas. This understanding will, in turn, provide a basis for the management of wildlands for the production of water as well as for timber, forage, wildlife, and recreation.

First reports on the theory of measuring soil moisture with neutrons were published in 1950 (Belcher et al. 1950). Equipment using the theory has since been developed. A brief review of the theory, our experience with one commercially available probe, and some advantages and limitations of the method are presented here.

Theory of Operation

The neutron method is a measurement of the number of hydrogen nuclei that are present in the soil (Carlton 1957; Van Bavel 1958). The physical principles, in brief, are as follows:

1. Fast neutrons emitted from a radioactive source lowered into the soil are slowed down or "moderated" by collisions with hydrogen atoms in the surrounding material.

2. Most of the hydrogen in the soil is in water molecules. Therefore, the number of moderated or slow neutrons is a measure of the water content of the soil.

3. Although neutron moderation by materials other than water may occur, it is negligible in most soils. The occurrence of slow neutrons is practically independent of soil texture, structure, and aggregation.

Equipment to put the neutron theory into field soil moisture sampling use has been designed several ways. Three companies are known who have produced the equipment commercially. They are Nuclear-Chicago Corporation, 223 West Erie Street, Chicago 10, Illinois; Troxler Electrical Laboratories, P.O. Box 5253, Raleigh, North Carolina; and William E. Johnson Associates, Inc., Empire State Building, New York, N. Y.

Figure 1. Nuclear soil moisture probe about to be lowered into access tube.

In addition, many researchers have designed and built their own equipment. Data used in this report were obtained with a Nuclear-Chicago P19 moisture probe with its fast-neutron source and slow-neutron detector. The presence and number of slow neutrons were recorded and timed on a Nuclear-Chicago Model 2800 portable scaler (Figure 1).

The number of slow neutrons counted per minute can be directly related to soil moisture per cent by volume. The calibration curve, prepared from known moisture standards, is essentially a straight line through the range of soil moistures most commonly encountered, about 5 to 50% by volume. The slope of the curve depends on the strength of the radioactive source and the electronic composition of the recording equipment. In our equipment, a change of 1% moisture by volume is recorded as a change of about 150 counts per minute.

Disintegrations of a radioactive material do not occur regularly but have a random distribution in time. Probability theory provides the information that the fractional error associated with a determination of the count rate is inversely proportional to the square root of the total number of counts accumulated (Nuclear-Chicago 1958). A close approximation of the error in terms of moisture per cent by volume may be found from the following formula:

$$E = \frac{K}{\sqrt{S}} \cdot \frac{\sqrt{Pv}}{\sqrt{T}}$$

where

E = error in per cent moisture by volume
K = constant determined from selected probability level
S = slope of calibration curve
Pv = moisture per cent by volume in sample
T = time over which counts are collected for any one reading.

With our probe at the San Dimas Experimental Forest[1], a 2-minute counting rate provided a random error of less than 0.50% moisture by volume or less than 0.06 inches of water per foot of soil over the range of soil moisture from 0 to 20% (Figure 2). At any moisture value less than 50% by volume, a 2-minute reading provided a random error of less than 0.10 inch of water per foot of soil.

Operation of Equipment

The neutron probe is a stainless steel cylinder 13¾ inches long by 1½ inches in diameter. This contains the separately encapsuled radioactive elements (5 millicuries of finely ground radium-beryllium mixture), the enriched BF^3 slow neutron detector tube, and a transistorized preamplifier. The probe is lowered to the desired depth into a previously prepared hole. A coaxial cable connects the probe to the scaler. If reinforced, the cable may be used to lower the probe; if not, a separate chain is attached to the probe top.

The portable scaler electronically counts and indicates the number of pulses received from the slow neutron detector tube. The count is indicated on 5 glow tubes, allowing a maximum indication of 99,999 counts. A spring-wound timer permits predetermination of counting time. An integral high-voltage supply provides DC voltage from 700 to 1,500 volts for operation of the detector. An internal wet-cell battery gives complete portability, but AC line current may also be used. The battery automatically recharges to the proper level when AC current is connected.

The necessity of having a previously prepared "hole-in-the-ground" has introduced problems, especially in wildland and rocky soils. Holes

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[1] Maintained by the Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, in cooperation with the State of California, Dept. of Natural Resources, Division of Forestry.

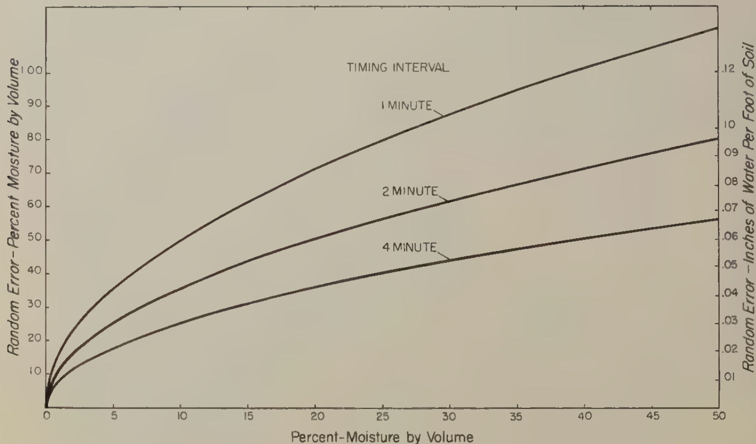

Figure 2. Random errors associated with P19 Moisture Probe No. 61 and Model 2800 Scaler No. 80 for three timing intervals.

have been prepared with soil sampling tubes, soil augers, and powered drills. In an extreme example, pits were dug (Marston 1958). Steel, aluminum, and brass tubing have been used to maintain an open hole. We selected 21-gage, 1-5/8-inch O.D. seamless brass tubing because of its known durability. Since an oversize hole was developed by the drilling procedures, dry fine soil was carefully sifted around the tube. Vibrating the tube during backfilling seemed to insure a snug fit and no loosening of tubes has been noticed. The tube extends 6 inches above the ground to provide support for the shielded probe.

In operation, the probe in its shield is placed on top of the access tube. It is then lowered through the shield to the desired depth. The probe may also be removed from the shield and lowered directly into the hole (Figure 1). The timer is set for the desired time interval, usually 1 or 2 minutes, and counts accumulated for that period. (Other counting equipment may record either the length of time required to obtain a pre-set number of counts or the rate at which the slow neutrons are counted by the detector tube.) Our timer has been found to reproduce a 2-minute time interval within ± $\frac{1}{2}$ second on practically every occasion. Manual controls also permit the use of a stop watch if greater accuracy is desired.

The 1 or 2 minutes needed for each measurement may be profitably spent by having the operator determine the counts per minute and the moisture per cent by volume. The moisture per cent is then plotted on a graph containing the results of previous samplings. This plotting provides a convenient way of following the advance of depletion of moisture from any site. Detailed compilation is usually deferred to the office. The nature of the data makes them amenable to electronic computer calculation if such is desired.

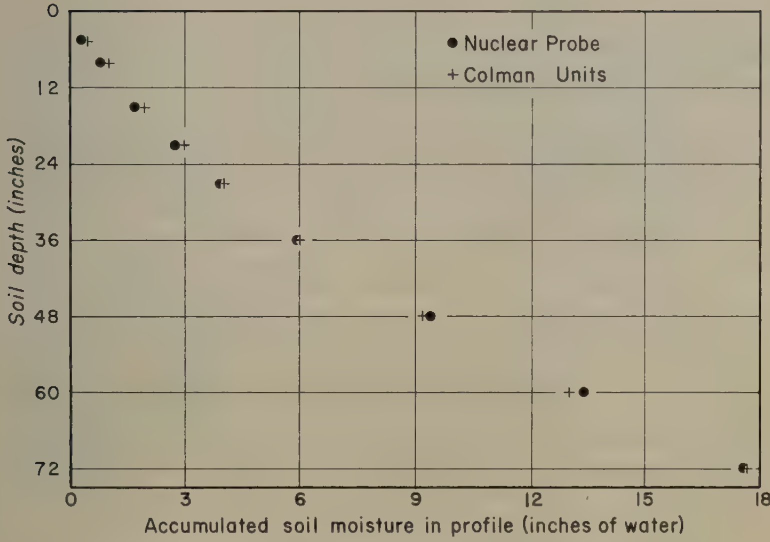

Figure 3. Accumulated moisture in soil profile of grass-covered lysimeter, July 16, 1958.

Results

Lysimeters at the San Dimas Experimental Forest provided an excellent location to gain experience in operation of the probe and scaler. These runoff and percolation tanks with concrete sides and bottom, each 10 feet by 21 feet by 6 feet deep, were established in 1937 (Sinclair and Patric 1959). The soil in each is a homogeneous sandy clay loam, mixed from local soils. Colman electrical resistance units (Colman and Hendrix 1949) had been installed in selected lysimeters by 1952.

First tests of the probe in the lysimeters were gratifying. On July 16, 1958, the nuclear probe recorded 17.72 inches of water in the 6-foot soil profile of a grass-covered lysimeter, while the Colman units indicated 17.65 inches (Figure 3). Five days previously the Colman units had recorded 17.74 inches, and gravimetric sampling had shown 17.59 inches (Merriam 1959).

These tests indicated to us that the manufacturer's calibration curve—made in steel tubing—could be used with our brass tubing. We had hoped that this would be true since the outside diameter of the tubings were the same, the wall thickness varied by only 0.003 inch, and the densities (weight per linear foot) of the two tubes were essentially the same. Tubing of other materials, diameters, and wall thicknesses may require modified calibration curves.

Since the lysimeter tests, probe readings have been taken in brush and pine plots, and at 23 locations in the headwaters of an experimental watershed. One purpose of the soil moisture studies in the watersheds

is to determine the changes in soil moisture loss following aerial spraying of herbicides. The decrease in water content of the upper 10 feet of soil between April 22, 1959 and October 22, 1959 at four sampling locations is shown in the following tabulation:

Aspect and treatment	Decrease in soil moisture
West-facing	
Control	5.18 inches
Sprayed	4.10 "
East-facing	
Control	6.35 "
Sprayed	3.18 "

Water use by plants before April 22 was probably greater on the control than on the sprayed sites. On that date the average water content of the upper 10 feet of soil on the control sites was only 15.8 inches, while the sprayed sites contained 20.7 inches of soil moisture. An additional 2.10 inches of precipitation fell during the period April 22 to October 22 in small storms. A more complete foliage kill on the east-facing slope may account for the greater reduction due to spraying on that site.

Conclusion

The neutron probe provides soil scientists and others a research tool that can take its place with gravimetric sampling, electrical resistance techniques, and tensiometers as a "standard" method in soil moisture studies. Some advantages of this new technique are:

1. Sampling is limited only by the depth to which access tubes are installed.

2. Successive samples can be taken from the same point and additional samples at intermediate points may be made if desired.

3. One calibration curve suffices for a wide variety of soils. Further, readings are converted directly to soil moisture per cent by volume so that variations in bulk density do not enter into determinations of equivalent depths of water for any soil depth.

4. Time required for soil moisture determinations with the neutron probe compares favorably with gravimetric and electrical resistance techniques. Resistance units require the greatest installation, calibration and computation time but may be read very rapidly when installed. Gravimetric sampling requires laboratory time for weighing, drying, and reweighing, besides time for field sampling and computation. Probe sampling requires about $2\frac{1}{2}$ minutes per 2-minute sample plus a few minutes at each site to check the operation of the probe in the standard shield. Computation of soil moisture is most rapid with probe data.

Disadvantages of the neutron probe include radiation hazard unless recommended safety precautions are carefully followed. The original cost of the sampling equipment is high. Although the scaler and probe are well encased and completely portable, they are too heavy for one person to carry very far, but manufacturers may eventually be able to design lighter shielding and more completely transistorized circuitry. Moisture measurements in the upper 12 inches of the soil may require a correction factor because of the escape of neutrons into the air. However, special probes for moisture determinations in this zone are available. In addition, both surface and depth density probes are available for determining the bulk density of soil in place.

All in all, the neutron probe can speed soil moisture measurements a great deal. In ten years it has been put to work in many locations. The next ten years will undoubtedly bring a greatly increased understanding of soil-water relations and the application of this knowledge to the wise management of wildland resources.

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PRESENT STATUS OF OAK MANAGEMENT IN WISCONSIN

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INTRODUCTION

Oak forests occupy about 2.2 million acres in Wisconsin (Wisconsin Conservation Department, 1958a, b, c; 1959a, b). The best and most extensive stands occur on the upland loam and silt loam soil (Wilde et al., 1949) in the highly developed dairy region in the southern half of the State. Unfortunately, this geographic association of trees and cows is very detrimental to the woodlands, almost three-fourths of which are pastured (Scholz, 1951).

In 1953, the volume of oak[1] sawtimber was estimated at 4.1 billion board feet, about one-third of the total hardwood sawtimber in Wisconsin (U.S. Forest Service, 1958). Northern red oak (Quercus rubra L.) comprised 75 per cent of this total. (For scientific and common names used, see Little, 1953.)

These figures show that the patchwork of oakwoods interspersed with agricultural fields and open pastures in the dairy country is a first-line timber resource for Wisconsin.

SILVICULTURAL PROBLEMS AND PROGRESS

Some progress has been made in acquiring background information for better management of the oak farmwoods in the State.

First, the woods must be completely protected from livestock and fire. This is a minimum silvical requirement. The next and most obvious need is to "clean up" the stand and get rid of defective trees and unwanted species. Since such improvement cuttings usually yield enough salable products to pay their way (Scholz and DeVriend, 1951), it is entirely feasible to build up the volume of an oak forest and improve its composition, timber quality, and value by this relatively simply silvicultural treatment (Arend and Monroe, 1950 and Scholz and Trenk, 1959).

If there is a market for products cut from cordwood-size trees, cultural work can be started as soon as the main stand reaches the small-pole stage (Scholz, 1952a) but overcutting must be avoided. This is particularly true with regard to crop trees because northern red oak and white oak do not attain maximum timber quality until they reach a diameter of at least 16 to 18 inches (Scholz, 1946).

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[1]Excludes northern pin (scrub) oak (Q. ellipsoidalis E.J. Hill). Although this species occurs in fairly pure, often extensive stands on dry, sandy sites throughout the three Lake States, it rarely yields sawtimber of acceptable commercial quality.

While intermediate harvests of various kinds provide a practical method of interim management, they do little to solve the ultimate silvicultural objective of regenerating the stand. This must be done by the time the overstory matures—usually at an age of 80 to 120 years, depending on site. The main problem is to secure an adequate restocking of northern red oak, the most valuable species. This regeneration preferably should be of seedling or seedling-sprout origin, for even first-generation coppice may lack the vigor and quality for satisfactory growing stock (Scholz, 1948).

Fairly complete information is available on the physical characteristics of northern red oak acorns, frequency of crops (U.S. Forest Service, 1948), and the extent to which insects, animals, and pathogens damage or destroy the seed, both before and after it falls to the ground (Korstain, 1927 and Gysel, 1957). Beyond this point, however, very little is known about oak regeneration problems as they relate to Wisconsin.

What about northern red oak seedlings: Can they compete successfully with the herbaceous vegetation and woody shrubs which occur naturally in the oak stands? If not, how much shade and competition can they tolerate? Even when a mixed-oak farmwoods is protected from fire and livestock, are there enough of these seedlings per acre to restock the stand adequately or must this species be propagated in part by direct seeding or by planting? Why do so few of these seedlings ever reach the sapling stage of development under the closed canopy of the overstory trees?

Although these questions are still unanswered, a considerable amount of basic information on northern red oak, especially its growth and yield and its response to various environmental factors, has been obtained by a number of technical workers.

In Wisconsin, as elsewhere throughout most of its natural range, this tree makes excellent growth on the better sites (Sander, 1957). Gross sawtimber yields of 14 thousand to 21 thousand board feet per acre have been recorded for 100-year-old, well-stocked stands in the southwestern part of the State (Gevorkiantz and Scholz, 1948). These woodlands are typically even-aged (Scholz, 1952b).

Northern red oak is quite sensitive to differences in the soil-moisture regime. It attains optimum development and timber quality on moist, fairly deep silt loam soils in the upper Mississippi region (Youngberg and and Scholz, 1950).

In southern Michigan, this species was the principal tree in the overstory on good sites (finer textured soils), but on areas which were characteristically sandy or otherwise low in water-holding capacity it lost its place of dominance to black oak (Quercus velutina Lam.) and white oak (Q. alba L.) (Gysel and Arend, 1953). The same workers also found that the yields of northern red and black oak could be correlated with both slope position and gradient (Arend and Gysel, 1951). Steep slopes (30 per cent or more) were less productive—as measured by the volume of the average dominant and codominant tree—than moderate ones, and lower slopes typically out-yielded upper slopes. The exposure, however, had only a minor effect on growth rates.

This finding is somewhat at variance with that for a similar study in

northeastern Iowa where "north and east aspects were found to have site index values 8 to 12 points higher than similar sites on south and west aspects" (Einspahr and McComb, 1951).

Unlike most hardwoods that form moderately pure, even-aged stands of good density, northern red oak is fairly tolerant to shade, ranking in this respect about midway between light-demanding quaking aspen (Populus tremuloides Michx.) and shade-enduring sugar maple (Acer saccharum Marsh.) (Curtis and McIntosh, 1950; Curtis, 1959). However, the fact that seedlings of this species seldom attain sapling size in mature closed stands, even when these areas are protected from fire and grazing, suggests that more sunlight may be required in its juvenile stage than in its later life.

RESULTS OF RECENT RESEARCH

A number of experiments are being carried on in Wisconsin to learn more about the silvicultural requirements of the mixed-oak forest type. The investigations discussed below are conducted in two State-owned woods, the Hardies Creek and Dundee tracts administered under the general provisions of the Timber Harvest Forest program[2] started in 1945 (Trenk and Abbott, 1947) (Fig. 1).

To facilitate discussion, results of studies are grouped as follows:

1. The kind and amount of tree seedlings found in well-stocked oak woodlands.
2. Relationship between the density of this natural regeneration and its topographic location (aspect of site and its position on the slope) and severity of competition by the herbaceous-woody shrub complex.
3. Direct seedings and plantings of northern red oak.
4. Experiments in (a) clear cutting and (b) shelterwood cutting.

Kind and Amount of Regeneration

During the past 12 years, periodic counts of tree seedlings in two timber harvest forests where northern red oak is the key species appear to justify several tentative conclusions.

Of first importance is the cyclic variation in the amount of regeneration per acre in these well-stocked stands. For northern red oak, the range between the highest and lowest years was 10 to 1 on the Dundee tract and 3 to 1 on the Hardies Creek tract (Table 1). In an area where sugar maple, white ash, elm, and other light-seeded species occupied a dominant place in the overstory (Dundee Woods) the total number of all hardwood seedlings was substantially higher than in an area of almost pure oak (Hardies Creek tract).

At 100 years of age on medium to very good sites, well-stocked mixed-oak stands have 100 to 125 dominant trees per acre, of which 75 to 94 normally will be northern red oak (Gevorkiantz and Scholz, 1948). Thus,

[2]This is a cooperative project by the Agricultural Extension Service, University of Wisconsin; the Wisconsin Conservation Department; and the Lake States Forest Experiment Station, Forest Service, U.S. Department of Agriculture.

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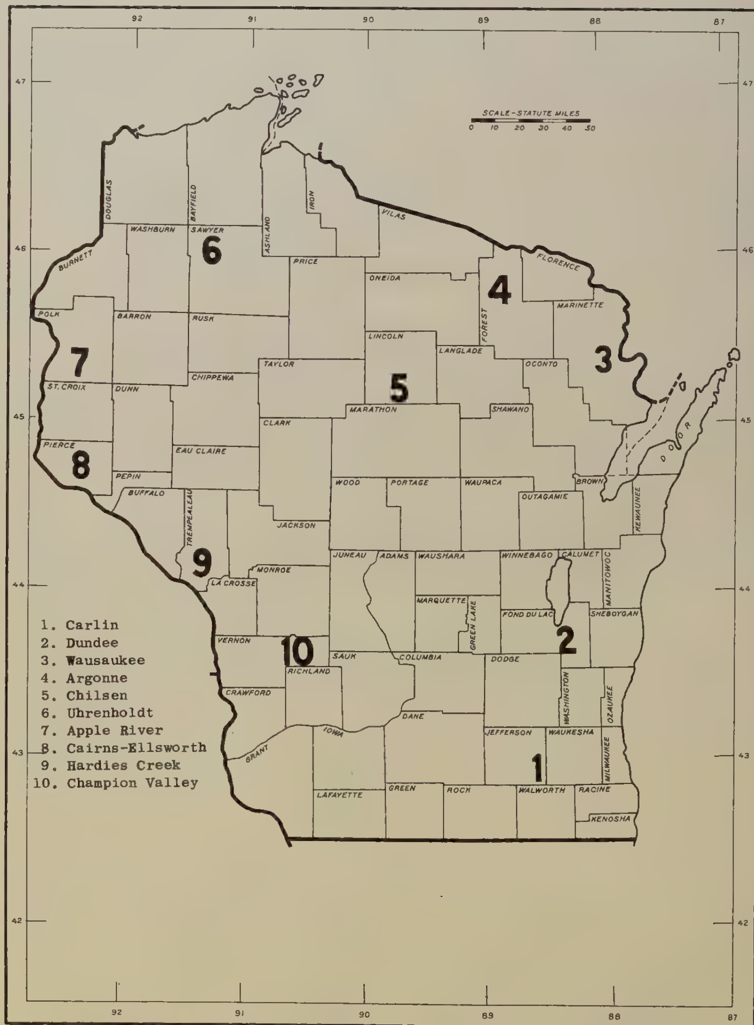

Fig. 1. Location of Wisconsin's 10 Timber Harvest Forests

Table 1. Variability in the Amount of Natural Regeneration in Two Mixed-Oak Stands

Year	Number of milacres	Number of seedlings per acre[1] Red oak	All species
		Dundee Timber Harvest Forest	
1947	50	460	8,660
1956	56	893	1,179
1957	25	4,520	11,520
1959	85	1,518	6,376
		Hardies Creek Timber Harvest Forest	
1951	586	1,137	2,573
1952	100	770	1,780
1958	80	2,438	3,875

[1]Includes only trees less than 4.5 feet tall.

the Hardies Creek-Dundee seedling counts indicate that natural regeneration is sufficient to restock these areas, providing 10 to 20 per cent of the young trees can be brought through to maturity.

Periodic regeneration counts also provide a clue relative to the ultimate competition between species. For example, the most recent milacre tallies on each timber harvest forest show that northern red oak accounted for only 24 per cent of all hardwood seedlings in the Dundee Woods as compared to 63 per cent on the Hardies Creek tract.

The numerical inferiority of the oak in the Dundee Woods is made more serious by the fact that the remaining 76 per cent of the reproduction includes such shade-tolerant trees as sugar maple, basswood, and elm—species that are scarce or absent on the Hardies Creek tract. Information of this kind is useful in determining the marking policy for a specific parcel of timber.

The possibility of increasing the number of northern red oak seedlings by improving the condition of the seedbed has been investigated on the Hardies Creek tract. On terrain that permitted the use of an Atens disk, soil scarification in conjunction with a bumper acorn crop more than tripled the 1- and 2-year stocking of these small trees as compared to undisked check areas (Scholz, 1955a). This margin of superiority, however, had largely disappeared by the end of the seventh year (Scholz, 1959) in this lightly-thinned, mature stand. Possibly a substantial percentage of these seedlings might have been saved by a fairly heavy cut in the overstory. This matter deserves further study even though natural regeneration on the two timber harvest forests as shown in Table 1 now appears adequate without special measures.

Effect of Topography

Among foresters southern exposures, steep gradients, and upper slopes are thought to be less hospitable for northern red oak seedlings

than northern aspects, slight-to-moderate gradients, and middle and lower slopes. To test this relationship, the 1951 regeneration counts for the Hardies Creek tract were analyzed. This particular area was chosen because the 53-acre unit is crisscrossed by ridges and ravines and is well stocked with mature, nearly pure stands of northern red oak. Furthermore the 586-milacre sample of seedling tallies covered the entire range of site conditions found there.

On this area—and for this stand—there seemed to be no significant difference between the stocking of northern red oak seedlings on the warmer south- and southwest-facing slopes then on the west and southeast slopes (Table 2). However, the position-on-slope factor deserves more study because the middle and lower slopes had a higher density of northern red oak seedlings than did upper slope-ridge-top situations.

This same influence of topographic location has been observed on the Dundee Forest where the ridges consist of accumulations of gravelly glacial till. Initial tallies for 85 permanent milacre sampling points, spaced at half-chain intervals and equally distributed between a lower slope-hardwood flat complex and a middle slope-upper slope site, gave counts of 2, 070 and 952 northern red oak seedlings per acre, respectively, for the two contiguous areas.

Another point of silvicultural interest was that some tree species occurred in greater numbers on certain topographic situations. On both the Hardies Creek and Dundee Forests, while oak and shagbark hickory (Carya ovata (Mill.) K. Koch) seedlings were more common on the hotter exposures and drier slope positions, whereas those of American basswood (Tilia americana L.) were more abundant on the cooler and moister sites.

This ecological information is not now used in managing the mixed-oak type for two reasons. First, further study is needed. Second, seedlings of the better tree species throughout the average woodland seem abundant enough for satisfacotry restocking providing a fair share of these young

Table 2. Average Number of Hardwood Seedlings Per Acre, by Exposure and Slope Categories
Hardies Creek Timber Harvest Forest

Topographic situation	Number of seedlings per acre[1]: Northern red oak	White oak	All species
Exposure:			
South and southwest	1, 038	250	2, 388
West to southeast	1, 152	79	2, 603
Position on slope:			
Upper slope and ridge	723	121	1, 781
Middle slope	1, 246	125	2, 846
Lower slope	1, 680	0	3, 440

[1]Includes only trees less than 4.5 feet tall.

trees can be brought to maturity. Consequently, topography as referred to in Table 2, does not seem to be a limiting factor to silvicultural success—at least in the initial stages of stand development.

Vegetative Competition

The crux of reestablishing northern red oak from natural regeneration is to be able to control the competing vegetation. However, to accomplish this objective in the mixed-oak forests of Wisconsin, one is faced with a dilemma—to cut lightly or to cut heavily.

On the other hand, these small tress cannot develop under the closed canopy of the main stands. An analysis of seedling-height data for the Hardies Creek and Dundee tracts illustrates this point. Over a 12-year period, 1,351 northern red oak seedlings were measured on an aggregate sample of 983 milacres on these two areas. Their size distribution was as follows:

Height Class Inches	Total Trees	
	No.	Per cent
Less than 6 inches	785	58.1
6 to 53 inches	562	41.6
54 inches (4.5 feet and taller)	4	0.3
Total	1,351	100.0

The competitive difficulties of these small trees, even in well-stocked stands with a closed canopy of overstory trees, often are made worse by the ground-cover vegetation. From one 5-year study, it was found that Kentucky bluegrass (*Poa pratensis* L.) sod and dense, colony-forming plants such as sensitivefern (*Onoclea sensibilis* L.) created the most unsatisfactory conditions for germination, survival, and growth; whereas a *sparse* stocking of woody shrubs was less detrimental (Scholz, 1955b).

In conjunction with the 1951 reproduction counts, the competing vegetation was arbitrarily rated as "light" if it occupied or shaded less than one-third of the total ground area; when it occupied between one-third and two-thirds it was classed as "medium"; two-thirds or more was classed as "heavy." The following tabulation shows the effect of competition by woody shrubs and herbaceous plants upon the number of trees per acre:

Density of vegetation	No. of milacres in each conditional class	No. of tree seedlings per acre	
		No. red oak	All hardwoods
Light	212	2,005	4,188
Medium	201	920	2,298
Heavy	173	324	913
Total or average	586	1,137	2,573

From these observations it appears that the density of the overstory inhibits the growth of both the tree seedlings and the competing vegetation. Heavy cutting upsets this balance, and therein is the dilemma.

The stand must be opened up to stimulate the tree seedlings, especially those of northern red oak, but unless this is done gradually, the competing vegetation may suppress and kill the young trees. To measure such

competition quantitatively, five replicated seedings and three replicated plantings were established in 1952 and 1953 on the Hardies Creek Forest. These plots occupy an open, but recently timbered, forest site which receives full overhead light. Half the area of each unit was kept free of overtopping herbaceous vegetation (weeded) and half was allowed to develop in a natural way.

Throughout this study, mortality has been higher and height growth poorer on the undisturbed check areas than on the adjacent weeded strips. At the end of the fourth year northern red oak seedlings on 25 1-chain-long check rows showed 90 per cent survival and an average height of 11.9 inches compared with 100 per cent survival and an average height of 15.1 inches on 25 weeded rows. Survival data are expressed as a percentage of the total trees at the end of the second year.

Blackberries (Rubus spp.) reduced the stocking and growth of northern red oak seedlings more drastically than any other kind of vegetation. On one seeded plot where this woody shrub occurred as a dense thicket, 55 per cent of the trees were killed between the second and fourth years. Seedlings that survived made very poor growth; they averaged 5.4 inches in total height as compared to 12.3 inches for other unweeded strips where blackberry was of minor consequence.

Observations on the Dundee Forest provide additional evidence of what happens when juvenile northern red oak are overtopped by this brier (Scholz and DeVriend, 1957). Thus, severe competition (mainly blackberry) reduced the per-acre stocking of these small trees from 3,648 in 1951 to 696 in 1955 (a loss of 81 per cent). Comparable figures for light-to-medium competition were 5,000 and 3,190 respectively.

Even though certain combinations of woody shrubs or herbaceous plants virtually wipe out the tree regeneration on small areas, these voids seldom are of major consequence for an entire woodlot. Rather, the information obtained to date indicates that there are enough seedlings of northern red oak and other species to restock most sites in well managed stands.

Seedings and Plantings

The main purpose of seeding and planting experiments was to determine the feasibility of perpetuating northern red oak by artificial methods. As previously stated, five plots on the Hardies Creek Forest were seeded with acorns of this species in the spring of 1952. In the fall of the following year, three more plots were planted with 2-0 nursery stock. This means that the small trees on all eight plots are of identical age.

In addition to the information on the effect of vegetative competition upon growth and survival of the seedlings, these plots have provided other valuable data. For example, some areas were fenced to keep out deer; others were fenced to exclude both deer and rabbits; and a third group was not fenced at all.

Various animals have caused trouble at one time or another. Squirrels and mice undoubtedly pilfered the acorns in the majority of 216 seed spots that have remained blank since the first examination in 1952. Girdling by mice and clipping by rabbits have damaged many trees, some seriously, but have killed very few. The incidence of deer browsing has been low and of minor importance even though these animals show a pref-

erence for the terminal shoots of the tallest and most thrifty trees. In its current proportions, biological damage is not interfering too seriously with natural regeneration, but the future situation will bear watching.

Northern red oak outplanted on three plots as 2-0 nursery stock in 1953 looked very good 2 years later. Survival for weeded strips of five rows each and for their untreated checks was 94 and 89 per cent, respectively. Height growth also was very satisfactory as shown by the following averages for the five direct seedings and three plantings:

Weeded strips:	
4-0 seedlings	(864 trees) - 15.1 inches
2-2 plants	(283 trees) - 20.1 inches
Unweeded checks:	
4-0 seedlings	(667 trees) - 11.9 inches
2-2 plants	(267 trees) - 12.8 inches

Only minor losses occurred on the eight seedings and plantings during 1956 to 1959. Moreover, many of the trees had grown to heights of 4 to 6 feet under relatively severe competition and 6 to 8 feet on sites kept free of overtopping vegetation. Thus it appears feasible to regenerate northern red oak by planting acorns or nursery stock if this becomes a silvicultural necessity.

Experimental Cuttings

Clear cutting.—A 2-acre clear cutting was made in a mature stand of mixed oak in 1949 on the Dundee Forest. This study complemented the Hardies Creek seeding and planting tests by providing an opportunity to compare the survival and growth of northern red oak reproduction of natural origin with that of planted trees.

The results have been encouraging. While blackberries shaded out much of the regeneration on a few small areas, the stocking of tree seedlings was excellent elsewhere. Five years after cutting, there were 1,220 northern red oak and 5,860 other valuable hardwoods per acre (Scholz and DeVriend, 1957). About all that needs to be done now to hasten restocking on this 2-acre unit is to keep the eastern hophornbeam in check by an occasional weeding such as was done in 1955.

It would be a serious mistake to use this single case study as justifiction for managing the mixed-oak forest type by clear cutting in small blocks. But it would be equally shortsighted to fail to explore the promising leads and silvicultural possibilities of this method of logging by additional and more elaborate experiments at an early date.

Shelterwood cuttings.—Upon the basis of present knowledge, the shelterwood system seems to be the logical silvicultural method for managing the mixed oak forests of Wisconsin.

Selection cuttings are not suitable because the main stand never is opened up enough by this method to permit the natural regeneration to advance beyond the small seedling stage. On the other hand, the complete removal of the overstory by clear cutting also creates problems. The small trees that have been released are stimulated by the additional light; but so are the woody shrubs and herbaceous plants associated with them. This leads to the somewhat paradoxical situation of accelerated growth by some seedlings and a high mortality rate among others that

are subjected to severe competition. The shelterwood system provides a workable compromise between selective logging and clear cutting by using two or three periodic harvests thus postponing complete removal of the overstory for 10 to 15 years.

Four shelterwood cuttings have been made on the Dundee and Hardies Creek Forests. The areas treated vary in size from 5.2 to 6.5 acres.

The first of these cultural operations was started in Compartment 1 of the Hardies Creek Woods in 1950.

An attempt was made in 1955 and again in 1957 to evaluate the effectiveness of this oldest cutting by taking regeneration counts on 123 milacres and 143 milacres, respectively. These tallies show that there were 2,244 northern red oak seedlings per acre in 1955, but only I,252 in 1957. Since a different group of milacres was examined each time, it is not safe to assume that there was a 44 per cent loss in stock during a 2-year period, but a substantial decrease in probable. This question can only be answered by taking additional samples.

Height growth data show that the small trees are making slow, but steady, progress in competition with other forms of vegetation. The following tabulation for northern red oak is typical of this trend:

Total height of seedlings (inches)	Percentage of seedlings in each height class in —	
	1955	1957
1-6	47	25
7-12	41	35
13-18	5	17
19-24	7	11
25-36		5
37-48		3
49-88		2
Total	100	100

As soon as there is definite assurance that the oak and other young hardwoods have outstripped the woody shrubs, the third (final) harvest cutting will be made.

It may be possible to shorten the total period required to establish natural regeneration by using a two-cut, instead of the more conventional three-cut, shelterwood system. To test this theory, the overstory of the stand in Compartment 3 of the Hardies Creek Timber Harvest Forest was given a heavy thinning from below in the fall of 1959.

The progress of this experimental cutting will be followed closely during the ensuing 5-year period to see what happens to the ground-strata vegetation. Unless the more open stand conditions (better light) benefit the tree seedlings more than the woody shrubs and herbaceous plants, there will be little to recommend the two-cut shelterwood system over the three-cut method.

Another practice that merits trial in conjunction with heavier cuttings is release. By mechanical, or perhaps chemical, means the oak seedlings can be favored and competing vegetation removed or retarded in

development. Workable and economical means of release need to be developed.

NEED FOR ADDITIONAL RESEARCH

During the past decade, case studies and short-duration experiments have provided valuable information in the mixed-oak forests of Wisconsin. Current cutting practices and silvicultural objectives are based upon the results of these exploratory projects. This type of program should be continued—and expanded—until it can be superseded by more formal, long-period studies.

Eventually, the management of the mixed-oak woodlands must be based upon fundamental investigations of the ecological and silvical requirements of individual tree species, especially northern red oak. These basic studies should cover the entire life span of a tree from its first-year seedling stage through maturity. This information, plus a better understanding of how to obtain and establish adequate natural regeneration, will provide all the "working tools" a forester needs to keep the oak lands of the State at a high level of productivity.

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THE ECOLOGICAL APPROACH AND USE OF PRESCRIBED BURNING IN SOUTHERN PINE SILVICULTURE

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Many Iowa State foresters of the 1940 vintage have shared three campus experiences with the writer. Possibly these have been duplicated in other forestry classrooms across the nation. I like to think I see in these three situations a pattern that is expressed repeatedly as a cycle in human experience. Let me see if these can be recalled and with the telling relate them to our subsequent attitudes in the development of forestry, and principally in silviculture.

Some may remember the all-night sessions as sophomores struggling to complete field maps before due date in Forestry 245. It wasn't the work, but the fellowship and attitudes that stand out. The relaxed atmosphere among "us chickens" usually encouraged a Don Quixote outburst at rather frequent intervals. Sure, we were neophyte idealists, and our spirit would carry us through great contributions!

With exposure to plant physiology, mensuration, history and policy, and especially "Hi-Gear's" thoroughly explained "horizontal cut" and finance lectures there eventually seemed to evolve a numb sort of group conformity. I wondered then, but realized later the profs did think of us as entities.

The third experience occurred during George Hartman's forest products course. How many times did he permit the class to rouse a heavy sleeper and then, of all things, proceed to repeat an important illustration for the laggard's benefit? Possibly we agree it was a humbling experience but there appears to be more. Concern was expressed here. Someone stepped off the path of "normal" human reaction long enough to challenge the student to get back in grace and stand as a prepared and responsible individual.

So went forestry school. Then, graduates had a rightful pride in their accumulation of class and field experience and were eager to press their knowledge to advantage in their first jobs. Again it seemed that this was where "spirit" and "opportunity" would have a toe-to-toe experience.

In this initial field experience it seemed that there apparently was a general reluctance to accept the ecological approach to forestry, and specifically to silviculture. "Conservation" was a popular by-word that helped bend many an ear and obtain support direly needed for conservative cutting and fire pre-suppression and control. Often, however, it has been observed that prolonged use of a soothing elixir may lead to a policy of commitment, rationalism, and day-to-day operation by justification.

In some areas foresters were prone to drift with the community pattern. Some who raised question were suppressed with seniority opinions.

Research in some fields was nonexistent or in infancy. Premises on southern pine ecology and silviculture were contested. Those able to marshall a few facts for defense against the two-edged sword of opinion were mostly keen observers who had unusual opportunity to witness field frequency patterns because of job stability.

One of the early resonant voices of stature that boomed out of the balmy Indian-summer atmosphere belonged to Professor H. H. Chapman (1912). Repeatedly he called to attention observations substantiating the views of early ecologists that in the absence of repeated fires, hardwood would gradually replace pine on southern Coastal Plain sites (Long 1888; Wells 1928). Chapman (1942) was among the first to note relative response of pine and hardwood to biotic and pyric influences and to suggest the use of fire as a silvicultural tool, first in longleaf pine (Pinus palustris Mill) management and then for loblolly pine (Pinus taeda L.).

A 1945 report summarized the effects of 2 to 5 controlled burns made in New Jersey since 1936 in oak-shortleaf and pitch pine stands to prepare pine seedbeds and control pine-hardwood ratios (Little et al. 1945).

By 1947 the research and experience shared by Bickford et al. and Squires broke down opposition to use of prescribed burning in longleaf and slash pine management. It should be noted that the earliest burning was principally for fire hazard reduction. Subsequently, it was recognized as a silvicultural tool to prepare seedbeds and control brownspot disease of longleaf pine.

A lull followed Chapman's proposal that fire should be used in preparing seedbeds for loblolly pine and subsequently for keeping associated hardwoods under control. The author listed the factors probably contributing to this lag as follows: (1) failure to recognize the ecological position of southern pine as a fire subclimax group; (2) lack of resource data showing the scope of hardwood encroachment, its limiting effect on pine regeneration, and subsequent economic implications; and (3) reluctance of forest administrators to probe the field for fear of spreading confusion in educational work because of the early stand to keep all fire out of the woods and possibly losing advances made and support for necessary protection against wildfire (Silker 1956).

Subsequently, it was also noted that some who advocate uneven-aged loblolly and shortleaf pine management evidenced a reluctance to consider hardwood encroachment as a natural consequence of plant succession toward the climax stage (Reynolds 1956). A recent release by Dean et al. (1959) indicates that the soils in Reynold's study area are classed as depositions of old loessial terraces. The author suggests these terrace soils are not typical of most sandy Coastal Plain soils and questions the recent inference that the same silvicultural approach, investment and margin-of-return ratios reported for study areas may be expected on nearby upland soils of northwest Louisiana and southwest Arkansas (Reynolds 1959). They enjoy an above-average pine regeneration and growth potential in spite of heavy understory hardwood populations because, it is believed, soil moisture storage and retention capacity are high. Reynolds acknowledges the competitive aspects of understory hardwoods by illustrating the need for regeneration release early in the stand history and a second hardwood treatment before rotation end. The first removal was assisted by a favorable local market for chemical wood.

Lacking this market, the two T.S.I. (timber stand improvement) treatments suggest a possible total investment of $10 to $15 or more per acre. These expenditures are not very competitive with total prescribed-burning costs for a rotation. Neither will the T.S.I. treatments limit total flora balances nor halt the plant succession pattern, creating and prolonging a subclimax condition favorable to pine, as will prescribed-burning.

In 1946 and shortly thereafter, several workers in the South, independently, began studying pine and hardwood relationships and initiated test burning for hardwood control. Chaiken's preliminary findings confirmed many of Chapman's observations but did not cover conditions and requirements for satisfactory burning (1949). The report of Ferguson et al. (1953) covered degree of hardwood killback by season of burn and type of fire in the upper Coastal Plain of East Texas but again no report was made on how to make burns.

Preliminary results of hardwood control research initiated in 1949 and procedures for effecting satisfactory burns in three predominant flatwood fuels were reported in 1953 by the Texas Forest Service (Silker 1953). In 1955 Bulletin 46 was released to expand on preliminary findings and present guides for effective and safe program burning for three fuel types and operable climatic conditions (Silker 1955).

Bulletin 46 is currently being revised to include observations on supplementary burning studies on upper Coastal Plain steep slopes, hardwood mortality data, plant succession response after burns and management features that should receive greater consideration. The following portion of this paper will be directed to abstracting the more important features of this revision.

THE STUDY

Only recently has there evolved near-majority agreement that southern pine is a subclimax group. Observations of field conditions indicate that the relatively thick, corky bark of pine limits heat transfer and little or no cambium-girdling results from light to moderate ground fires. Thin-barked hardwoods, on the other hand, are quite easily girdled by such fires and hardwood top-growth is killed back or complete plant mortality results from fire-kill or fungus rot. Such hardwood topkill or mortality sets back the normal plant succession trend toward hardwoods of a higher successional position. Repeated fires may so adequately limit hardwoods that only the most persistent bush-type plants can thrive. At this stage the site is relatively free from shade and hardwoods that would compete for moisture, and site condition appears favorable to even-aged pine reproduction whenever seed source and climate are adequate.

The research described in the following pages was begun under the premise that prescribed-burning in the pine-hardwood type (1) was a justifiable calculated risk; (2) would set back natural plant succession and leave the site in a condition favorable to regeneration and dominance by subclimax plants such as pine; (3) was the most economical tool to control plant succession when used in even-aged management; and (4) would be acceptable to technicians and land managers if fire behavior, degree of control, and effectiveness could be predicted under certain conditions.

Figure 1A. Cutover sawtimber-size pine-hardwood stand typical of many East Texas areas where wildfire has been excluded. Understory hardwoods dominate openings and prevent pine reproduction from becoming established where overstory pine has been selectively logged. Such areas should be prepared for pine reproduction cuts after hardwood invasion is controlled.

Figures 1A, 1B, and 2B illustrate the three predominant fuel types studied from 1949 through 1953 on flatwoods or rolling upper Coastal Plain sites. Spring, fall and winter burns were studied to determine if one or more seasons would give greater relative hardwood killback or would be more ideal for a given fuel type. Burns were made at two and three-year intervals to test desirable frequency. Treatments were applied to three-acre study plots and each treatment was replicated three times (Figures 1 and 2).

The burning on steep slopes was conducted during the period of 1956 to 1958 on rocky, "iron-ore" Boswell soils on north and south slopes exceeding 20%. A brief discussion of the three prevalent fuel conditions follows.

Cutover sawtimber-size pine-hardwood fuels lack uniformity and continuity of pine-straw. Total overstory basal area averaged about 60 square feet, of which hardwoods sometimes comprised 44%. Understory hardwoods of 1-inch diameter or under averaged 38,000 stems per acre

Figure 1B. Hardwood invasion in early stage under old-field stand of 18-year-old loblolly pine. Sweetgum, black gum, yaupon, holly and dogwood up to 2 inches in diameter predominate. This well-stocked stand with uniform pine-leaf litter is at optimum condition for the first prescribed burn to control understory hardwoods. One or more prescribed burns should be made before pine trees are thinned.

at test establishment. These stands contained more of the larger diameter hardwoods such as flowering dogwood (Cornus florida L.), southern red oak (Quercus falcata, Michaux) and occasionally white oak (Quercus alba L.) on terraces. Hardwood numbers and size evidenced in Figure 1A indicate a more advanced stage of hardwood succession than in the other fuels studied.

Pulpwood-size pine-hardwood fuels studied are typical of old-field stands. Stands averaged about 25 years in age. Figure 1B illustrates that fuels were moderate to heavy and uniform. Basal area per acre averaged 81 square feet and hardwoods contributed 12% to this total.

Southern wax myrtle (Myrica cerifera L.), holly (Ilex decidua Walt.), yaupon (Ilex vomitoria Ait.), black gum (Nyssa sylvatica Marsh), sweet gum (Liquidambar styraciflua L.), dogwood and Vaccinium (spp.) predominated in the 17,000 stems per acre, 1 inch in diameter or under, at test establishment.

Figure 2A. Plant association of longleaf pine, wax myrtle, and bunch-grasses on periodically-burned free-range at time of wildfire exclusion and fencing, 1926. (E.O. Siecke State Forest, Kirbyville, Texas.)

Pulpwood-size slash pine plantation fuels were uniform and heavy, with pine-straw draped in vines and bushes to a height of 15 feet or more in places. Stands varied from 18 to 22 years age at test establishment. The overstory averaged 104 square feet b.a. per acre, of which 1% was hardwoods. Understory hardwood stems 1 inch or less in diameter averaged 13,000 stems per acre.

RESULTS IN FUEL TYPES STUDIED

Table 1 lists the practical field factors to consider in planning and conducting understory hardwood-control burns in normal fuels in the several fuel types on flatwoods or steep-slope sites in East Texas. The author believes this guide may be used on other Coastal Plain sites in the South as long as fuels are comparable to East Texas conditions. Recommendations for desirable climatic conditions for burning moderate pine-hardwood fuels on flatwood sites in South Carolina (Lotti 1955) are identical with similar fuels listed in Table 1.

Figure 2B. First prescribed-burn in 12-year-old slash pine plantation to limit hardwood encroachment. See Figure 2A for condition of site in 1926 at time of state forest establishment.

Figure 2C. Advanced hardwood encroachment in plantation at age 24, to left of plow-line. To right, hardwood invasion effectively set back by 3 prescribed burns at 2-year intervals.

Table 1. Desirable environment for conducting prescribed burns in prevalent fuel types on flatwoods and steep slopes.

	Fuel type		
	Irregular stands	Uniform stands	
Desirable environment[1] and type of fire	Cut-over pine-hardwood saw-timber	Pulpwood pine-hardwood[2]	Slash pine plantations[3]
Overstory:	Pine basal area generally less than 70 sq. ft./acre	Pine basal area 70 sq. ft./acre or more	Pine basal area 70 sq. ft./acre or more
FLATWOODS AND ROLLING SITES: Fuel: Normal - no fresh dry slash			
Moisture content of upper fuels[4] (%)	3 to 6	4 to 8	8 to 20
Lower layer of fuel	Moist to dry	Moist	Moist to wet
Relative humidity (%)	20 to 40	40 to 70	50 to 95
Wind: Steady, north or south, 1+ mph preferable[5]			
Season, preferred order:	Fall, winter, spring.	Winter, spring, fall.	Winter, spring.
Air temperature:	No limit unless pine saplings present; then less than 50°F	Less than 80°F, as in winter and spring	Same, except 40°F or less in heavy, draped fuel
Type of fire	Strip-headfire of 20 to 120 feet, successive bands	Backfire, or strip-headfire of 10 to 120 feet, successive bands	1. Backfire in heavy draped fuel. 2. Backfire, first burn. 3. Repeat burns at short intervals, use 10 to 40 ft. successive strip-headfire at upper fuel and humidity levels.
Average flame height	3 feet	3 feet or less	3 feet or less
STEEP SLOPE SITES: Fuel: Normal - no fresh dry slash			
North aspect	Fuel moisture 5-8%. Lower layer fuel moist, other factors as above. Strip headfire 20-120 ft. bands with north wind.	F.M. 5-10%. Other factors as above. Backfire against north wind or strip-headfire 20-60 ft. bands with north wind.	---
South aspect	As above except strip-headfire 15-80 ft. bands with south wind.	F.M. 6-14%. Other factors as above. Backfire against south wind or strip-headfire 20-40 ft. with south wind.	---

Footnotes to Table 1.

[1] As expected to prevail during 1-3 p.m. period when burning index is highest. Fuel moisture, humidity, and rainfall data can be obtained from daily readings at district offices of the Texas Forest Service.
[2] Also equivalent to well-stocked sawtimber-size stands.
[3] Longleaf pine fuels usually are equivalent.
[4] As determined by basswood sticks. First levels to occur after 0.5 inch rain or more. Where these levels persist 3 weeks or more, do not burn, except on terraces or "terrace-equivalent" soils with light ironwood fuels.
[5] Wind velocity at ground level, inside the forest stand.
[6] Particularly less on steep slopes to limit pine crown scorch.

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The stands chosen for study contained understory hardwoods thought to be above the size subject to control by prescribed burning. This was planned so that the full effect of control by size-classes could be determined for each fuel type. More effective hardwood control could have been realized if burns had been made in younger stands where stems would have been smaller or if strip-headfires had been used in some cases during first burns.

Backfires were used during first burns in pulpwood-size pine-hardwood and slash pine fuels. This was planned to provide conservative burning. Strip-headfires were used during second and third burns, where possible, mainly to speed up burning operations but also to provide a wider stem-girdle on hardwoods over 3 inches in diameter in the pine-hardwood stands.

Successive strip-headfires were used during first burns in the irregular fuels on cutover areas. Burns were not as intense or uniform as desired on flatwood sites, mainly because of inexperience. Only 60% of the total treatment area carried fire. Second and third burns were delayed until a more desirable combination of fuel moisture, relative humidity and wind velocity prevailed. All minimum conditions listed in Table 1 had to be met to effect consistently good burns in these fuels. Second burns carried across 83% of the area and were generally of the intensity needed.

Successive strip-headfires were used on steep-slope sites. North slopes were burned only with north-prevailing winds and south slopes with southerly winds. Firing was started on the contour on the uphill side of the burning chance and progressed downhill by a series of successive, narrow strips. Narrow stripping was essential to limit vertical drift of heat and excessive crown-scorch of pine.

Data in Table 2 show the relative hardwood killback after 1 and 2 burns for the three fuel types prevalent on flatwood sites. Cumulative killback data illustrate the relative ease or difficulty of making effective burns by fuel type. They also indicate that there was no appreciable difference in hardwood killback by burning season or frequency. The season to burn should be given more weight when the needs of individual fuel types are considered. It is mostly a case of matching fuel volume and uniformity with season that will provide the most burning days for effective yet safe burn for each burning objective.

Table 2. Number of 1 to 5-inch diameter hardwoods per acre and per cent kill-back after 1 and 2 burns, by fuel type and season of burn.

Fuel type and season of burn	Burn interval (years)	Hardwood stems from 1 to 5-inch diameter: Number per acre	Percent killback: After 1st burn	Percent killback: After 2nd burn
Cut-over saw-timber pine-hardwood				
Fall	2	1330	13	27
Fall	3	856	10	29
Winter	2	961	12	32
Winter	3	1060	9	36
Average		1052	11	31
Pulpwood-size pine-hardwood				
Spring	2	1040	21	43
Spring	3	1094	17	41
Fall	2	759	24	40
Fall	3	1008	25	42
Winter	2	987	18	32
Winter	3	1019	21	42
Average		985	21	40
Pulpwood-size slash pine				
Spring	2	738	50	82
Spring	3	520	56	88
Fall	2	356	43	61
Fall	3	1307	70	77
Winter	2	517	42	84
Winter	3	498	46	70
Average		656	51	77

It is probably desirable at this point to discuss the where, when and how aspects of burning on flatwoods or rolling sites and cover the season and frequency of burn and potential pine damage.

BURNING ON FLATWOODS OR ROLLING SITES

1. Where to Burn

Effective burns can be made wherever fuel is adequate to carry fire and where most hardwoods are under 5 inches diameter near ground level. Except for extremely dry years, most cutover stands are not reasonable burning chances unless pine is fairly well distributed and shows an average basal area of at least 30 sq. ft. per acre.

Burning should be limited generally to normal fuels. Where fresh, dry logging slash is present, burning should be postponed usually for about 3 years. Then logging slash has dropped to the ground and is partly broken down.

It is also important to limit burning to plant associations that are susceptible to the girdling action by prescribed fire. Lately it has come to the author that there may be a close correlation among density, composition and thrift of certain plant associations and the soil province or condition supporting them. In like manner, the relative speed of plant succession is also thought to be related to soil condition and largely to moisture availability.

On relatively shallow, sandy soils above heavy clay, post oak (*Quercus stellata* Wangenh.), blackjack (*Q. marilandica* Muenchh.) and red oak usually predominate both in the overstory and understory in mixture with pine. Because of stem size, bark thickness and small amount of fuel, few such oaks would be girdled by prescribed-burning. Here, other methods of control are preferable, such as girdling, basal spraying or injection treatments with chemicals, or foliar spraying with chemicals by aerial or ground equipment. As depth and per cent of silt and clay in surface soil increase or the plasticity of subsoil increases in this plant association-soil province, sweet gum and associate plants of a higher successional position increase in frequency and vigor. Lately it has become evident to the author that a workable generalization can be made to define the "transition zone" between chances suitable for prescribed-burning and those best handled by other hardwood-control procedures. Over most of East Texas, burning for hardwood control may be prescribed and is practical wherever sweet gum and associated species of a higher successional position are present under fuels sufficient to carry fire. Elms (*Ulmus* spp.), red haw (*Crataegus* spp.), or occasionally yaupon may supplant sweet gum as a soil indicator in moisture-tension zones or at the western fringe of the pine belt (Silker 1960).

Prescribed-burning for hardwood control is usually recommended where pine regeneration is lacking, or is not needed at the time, or may be inadequate and should be sacrificed in deference to brush control. It is stressed here that burning is used in conjunction with and as a perquisite to even-aged pine management. There is no concern for scattered natural pine regeneration that volunteers periodically under young pine stands that later are to be reproduced by one seed crop. The silvicultural

objective is to fire-girdle all possible understory hardwoods and reduce the speed of plant succession expression early in the stand history. Periodic repeat burns are then made to keep re-sprout growth under control up to the regeneration cut. Just before the latter, two closely-spaced burns are anticipated to reduce re-sprout vigor and prolong the subclimax condition to favor pine seedbeds and juvenile seedling growth.

2. When to Burn

a. Place in Stand History

Prescribed-burning should be used early in the stand history before thinning reduces pine-fuel volume and uniformity, and while hardwoods are small, i.e., under 3 inches diameter near ground level (Figure 1B).

Hardwood invasion is generally well established in plantations or natural stands of age 10 to 15. Hardwood stems at this age are still within the size readily controlled by prescribed-burns. Early and periodic burns can keep these hardwoods under control and limit further hardwood invasion.

b. Pre-logging Burns

In older cutover stands prescribed-burning should precede any additional pine harvest cuts. The most effectively-burned portions of such stands are under existing pine where pine-straw is predominant in the litter, and fire will carry uniformly and with good intensity.

c. Season to Burn

Data showed no appreciable difference in hardwood killback by burning season.

The time of year to burn depends more on fuel type and burning objective than amount of hardwood killback effected by season. The conditions limiting safe and satisfactory burns and number of available burning days usually predetermine the season to burn.

First burns in slash pine plantations can be made with less risk during winter and early spring when fuel moisture is stable, air temperatures are low, and steady "norther" winds are frequent. Fuel of medium but uniform depth in pulpwood-size pine-hardwood stands generally can be burned any season of the year, but first burns involve less risk when made in winter and spring. On the other hand, fires are hard to move through cutover sawtimber-size stands with irregular light fuels. Combinations of low fuel moisture, low humidity and strong winds are necessary to move adequate fire through cutover fuels and plant associations on terraces and "terrace-equivalent" soils. These conditions usually occur during protracted dry periods in June and early fall.

Hazard-reduction burning has been carried out successfully on several young pine plantations and is being contemplated for vast areas. First burns are carried out when most saplings exceed 10-12 feet in height. Here, safe burns can be made and crown-scorch limited only when the underlayers of fuel are moist to wet, when winds are strong and steady,

and when air temperature is 50°F or less, and preferably less than 40°F, as in winter.

d. Frequency to Burn

Data show there was little difference in per cent of land area burned over between 2- and 3-year interval burns. Data in Table 2 show there was no appreciable difference in hardwood killback by burning season or frequency, within a fuel type.

The frequency of repeat burns depends mainly on the amount of killback on hardwood effected per burn and apparently on the soil-moisture availability of the site. It is desirable to plan the first repeat burn at not more than a three-year interval to complete girdling action on 3- to 5-inch diameter hardwoods. Such burning will also help measurably in reducing re-sprout vigor or in increasing mortality of stems girdled by the first burn.

Cumulative mortality of all understory hardwoods of 1-inch diameter or less was listed by fuel type, season of burn, and number of biennial burns (Silker 1956). Mortality of wax myrtle and sweet gum on fall-burned plots generally exceeded levels in other seasonal burns; it also exceeded levels reported by Lotti (1956) following annual summer fires in South Carolina. Other species did not show a consistent mortality pattern by season of burn and there was no appreciable difference in mortality on plots burned at two and three-year intervals. These data help explain reductions in volume of certain browse forage species reported by Lay (1956). They may also be useful in planning periodic maintenance burns to keep hardwoods at manageable levels for both timber production and wildlife use.

Average cumulative mortality in per cent of the most prevalent hardwoods that occur in the three fuel-types on flatwood sites was as follows after three burns: wax myrtle 55, yaupon 51, dogwood 77, sweetgum 39, holly 65, and French mulberry 14. The low mortality pattern expressed by French mulberry (Callicarpa americana L.) substantiates the 1953 view of the author that this species may be a useful plant indicator. Figure 3 illustrates the viewpoint that other undesirable understory hardwoods have been brought under control whenever this species predominates in the understory. It is thought additional study may show its usefulness as an indicator of desirable seedbed and site condition for pine regeneration.

Once hardwood succession has been effectively limited, as in Figure 3, burns can be spaced at 8- to 12-year intervals to maintain control over re-sprout growth. Two closely-spaced burns are anticipated just before the regeneration cut to reduce re-sprout vigor and prolong the subclimax condition to favor pine seedbeds and juvenile seedling growth. Once the even-aged pine regeneration has attained a height of 12 to 20 feet or a diameter of 2 inches or more, maintenance burns can be repeated as needed to keep control over hardwood re-sprout growth or new invasion.

Figure 3. Understory aspect showing predominance of French mulberry, Vaccinium spp., and sassafras (Sassafras albidum (Nutt.) Nees) following two prescribed burns in young pine-hardwood stands. Wherever French mulberry predominates, other undesirable hardwoods have been effectively brought under control.

3. How to Burn

The most important consideration is how to conduct a safe and satisfactory burn. The factors listed in Table 1 cover minimum and maximum conditions for burning specific prevalent fuel types.

The foregoing sections on season and frequency of burns covered some procedures for conducting burns by fuel type and burning objective. A few supplementary comments are offered to stress important points or interpret adaptation or limitation of the guide for variable fuels.

In using Table 1 it should be emphasized that the desirable climatic factors used to guide burning are those expected to prevail during the period 1 - 3 p.m. when the burning index is highest. Also, moisture content of upper fuels is that level that first occurs after precipitation of 0.5 inch or more. When fuel-moisture readings prevail at the lowest levels for three weeks or more, the underlayers of fuel are generally too dry for safe burning, except for the lightest fuels on terrace or "terrace-equivalent" sites where ironwood (Ostrya virginiana (Mill.) K. Koch.) generally predominates in the understory. The latter sites can

only be burned effectively under prevailing dry conditions that usually occur in June and through the fall.

Recent consideration of plant indicator-soil-site-ecological correlations by the author has identified a sizeable acreage of "terrace-equivalent" fuel. Figure 4 (Doering 1956) maps the Citronelle geologic formation in East Texas. It is also identified as extending east of the Mississippi River to the Ochlockonee River in northwest Florida. In East Texas, loblolly and shortleaf pine (P. echinata Mill.) and overstory and understory hardwoods typical of terrace soils occur even at ridgetop within the area designated as extending from Jasper to Willis and vicinity. Cutover fuels predominate and are classed as moderate to poor burning chances because the ever-present ironwood, red bay (Persea borbonia (L.) Spreng.), blue beech (Carpinus caroliniana Walt.), water oak (Q. nigra L.) and willow oak (Q. phellos L.) leaves are difficult to burn. Prolonged drying is necessary. At minimum pine basal area of 30 sq. ft. per acre, fuels should dry at least three weeks after a rain of 0.5 inch or more. Even then, some areas will not carry fire when burning at the ideal combination of -4% fuel moisture, 20 - 30% relative humidity, and 2 mph wind velocity, inside stand.

Recent field examinations in eastern Louisiana and western Mississippi indicate the mapped "Citronelle" formation does not express a "terrace-equivalent" plant association. In these areas the tight red clay subsoil lies at depths greater than 5 feet. Apparently the clay is not close enough to the surface to increase availability of moisture in the upper solum and site is therefore unable to support species such as ironwood, blue beech, and white, water and willow oaks. In this area east of the Mississippi River the plant association is comparable to that on medium-depth upland soils. The burning chance is therefore comparable to cutover fuels on upland areas.

A second variable, cutover fuel, occurs on the lower flatwoods. Water and willow oak, sweet gum and black gum predominate with loblolly pine. Drainage is moderate to poor with some flats containing scattered to heavy stands of palmetto (Sabal minor Jacq.). Because of slow drainage, most effective burning can be planned for late spring through early winter only after prolonged drying of 3 weeks or more. Limited burning days and the larger size of understory hardwoods help class such areas as limited burning chances.

Uniform fuels under well-stocked pulpwood-size pine-hardwood stands may usually be burned with either a backfire or a strip-headfire during the first burn. Choice in type of fire is based largely on moisture in lower layer of fuel and relative humidity at time of burn. These factors primarily control flame intensity and permissible width of successive strip-headfire and flame height. For instance, strip-headfire burning is usually not desirable when a low humidity (less than 50%) occurs during the late stage of the "drying cycle." There is not enough moisture in the lower fuel layer to offer resistance to the flame. The flame burns with considerable intensity and may exceed the desirable average height of 3 feet unless successive strips are less than 10 feet in width. Such narrow strips require excessive foot-travel that unduly tires torchmen. In such cases it is considered desirable to use the option of simultaneous backfiring of several adjacent blocks.

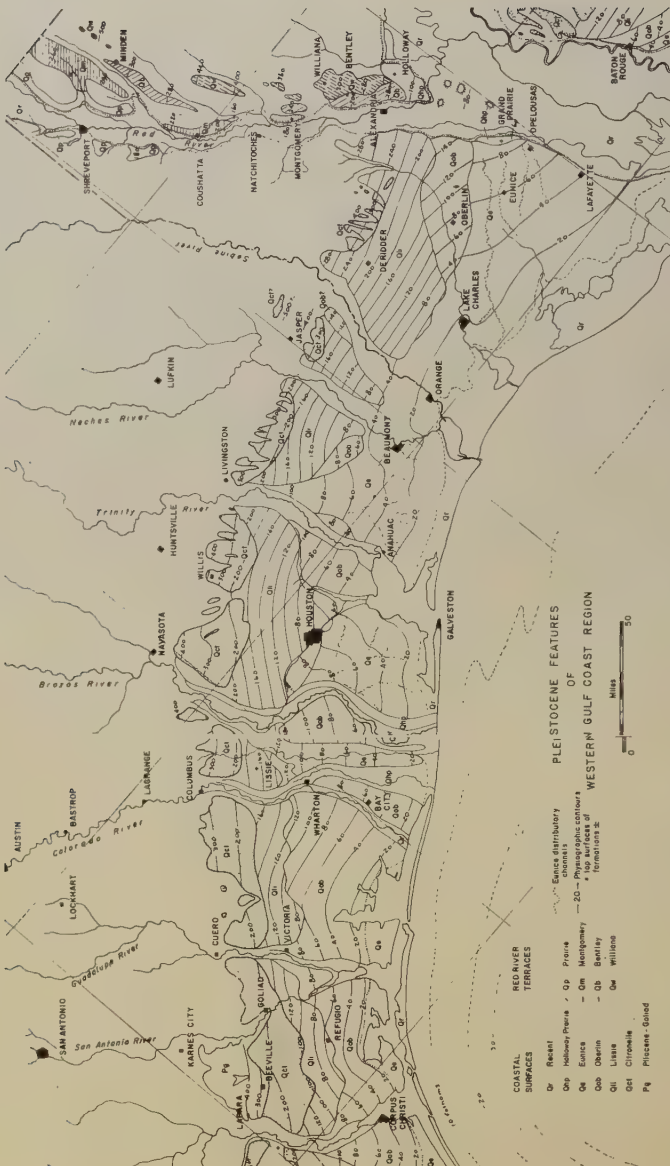

Figure 4. Physiography and areal geology of western part of Gulf Coast Region (Doering 1956).

Backfires move about 0.8 foot per minute in normal pine-hardwood fuels. Burning can seldom start before 11 a.m. and usually has to be completed by 6 p.m. before relative humidity increases and limits fire intensity and spread. Backfire chances are, therefore, subdivided by plowed lines laid out at 300 - 400 foot intervals in an east-west direction. Plowing is done a few days in advance of planned burn. This permits moving backfires short distances against prevailing north or south winds in East Texas. Long lines are preferred, when possible, since lines up to ½ mile in length can be serviced by one fill of most backfiring torches. Interior lines can be backfired simultaneously and one torchman can patrol one or more adjacent backfiring lines.

In the event fuel moisture and/or humidity are relatively high at time of burn, some of the plowed interior lines can be ignored and a larger block is fired by successive strip-headfires. The efficiency of backfire burning on lines prepared in advance usually offsets the loss of plowing investment in the event the strip-headfiring option is used.

4. Mortality and Damage of Overstory Pine

Neither season nor frequency of burn effect mortality of pine in the two pine-hardwood fuel types when burning is safe and conservative. Summer and fall burns should be avoided, however, when considering first and second burns in heavy fuels under slash pine plantations.

Prescribed burns generally can be made without inducing more than 1% mortality in overstory pine stems.

Crown-scorch may show on an occasional suppressed pine but, as Lotti stresses, overstory crown-scorch is evidence of carelessness or faulty technique. With little or no crown-scorch, no loss of pine growth should be anticipated.

When planning hazard-reduction burns in young pine plantations, prohibitive scorch and damage can be avoided by burning only in the winter when air temperature is 50°F or less, and preferably at temperatures below 40°. The lower whorl of live branches may be scorched, but buds are usually not damaged. Full crown is usually re-established the following spring.

Burning experience has shown that excessive heat transmission to pine cambium may occur when under layers of fuel are dry and fuel moisture is 3.5% or less. Pitch exudations usually appear on damaged trees between bark scales within a few weeks. Such damage can be avoided on moderate to uniform fuels by burning only when the lower layer of litter and humus is moist; burning, therefore, should usually cease when fuel moisture drops below 4%. The only critical point to watch in light irregular pine fuels is to limit flame height and intensity by narrowing the width of strip-headfires in occasional heavy patches of fuel so average flame height is not over 3 feet.

BURNING ON STEEP, UPPER COASTAL PLAIN SLOPES

Burning experience on steep slopes suggests that fuel character, aspect, climatic limitations, slope and burn frequency should be weighed in planning and conducting burns for comparable areas.

Fuel above the Boswell soil area was deeper (for given basal area of pine overstory) than is evidenced on flatwoods soils. This appears to be affected mostly by a relatively thick layer of unincorporated humus. The fuel appears to dry out more quickly after rain and burn with a greater intensity per given pine basal area, apparently as a result of its spongy nature, good aeration and the rapid drainage of site.

Hardwood species predominant on north and south slopes appear to be good indicators of both soil moisture and relative fuel moisture. A profusion of small sweet gum, dogwood, mulberry, holly and red oak made up the understory on north slopes. On south slopes there was a moderate to light stand of black haw (Viburnum prunifolium L.), tree huckleberry (V. rufidulum Raf.), and scattered sweet gum, post and blackjack oak. Under given climatic conditions north slope fuel moisture levels consistently averaged 2 to 3% higher than south slope fuels. The volume and nature of hardwood leaves on north slopes suggests burns should be planned at later stages of the "drying cycle" and usually at lower fuel moisture and relative humidity levels than on south slopes. Because of fuel variability and manner of handling fires, burns should be planned separately for north and south slopes.

The nature of the fuel and good drainage contribute to relatively rapid drying of fuels on steep slopes. Burning can generally be started earlier, after comparable rainfall, than similar flatwoods fuels. Burning should likewise cease earlier in a "drying cycle" than on flatwoods areas.

Slope contributes materially to crown-scorch of overstory pine, particularly where strip-headfires are used. Thermal currents permit more vertical heat drift during steep-slope burning than when burns are made on flatwood fuels. Live-crown level of pines is also closer to flame level on the uphill side.

Average flame height of strip-headfires should be conscientiously kept under 3 feet to prevent excessive pine crown-scorch from late spring through fall, when air temperatures are high. This can be done by consistently limiting the width of successive strip-headfires.

Burns should be planned and conducted only when the underlayers of litter and humus are moist to damp. This is desired to provide resistance to flame intensity and behavior and assure a residual mat of unburned fuel to prevent soil erosion. If this procedure is followed the author believes soil erosion on comparable sites will be limited and the gain from hardwood-succession control will outweigh heavily even occasional limited exposure of soil.

The spongy nature of the fuel leads one to expect greater fire intensity under given climatic conditions and pine basal area than on rolling or flatwoods soils. This apparently explains the greater degree of hardwood killback effected per burn on steep slopes. On south slopes it appears one uniform burn may be adequate to fire-girdle nearly all susceptible species under 4 inches diameter where fuels are uniform under well-stocked pine stands. On north slopes a minimum of two uniform burns will usually be needed to fire-girdle comparable hardwoods.

MANAGEMENT CONSIDERATIONS

Some of the following topics have been discussed in the preceding text. Additional comment is thought desirable to recapitulate and stress the more important features and relate minimum requirements to resource condition, personnel and cost considerations.

1. Hardwood Utilization

Hardwood numbers should be controlled by utilization, when possible. If sufficient numbers of quality hardwoods of commercial or near-commercial size are present, burning may be deferred until such material can be harvested. In some locations soil quality and favorable hardwood market may suggest reservation of areas for pine-hardwood management. In view of the relative productivity and value of hardwoods and pine on upland sites in the Coastal Plain, near-pure pine management is currently favored on most sites. Some terrace sites may also be covered by this objective. Prescribed-burning is viewed as the most practical and economical tool to keep pine in a predominant position.

Burning is not applied to eliminate hardwoods but rather to keep natural encroachment under control.

2. Soils-Plant Associations and Adaptability to Burning

It has previously been related that burning may be limited on slowly-drained, lower-flatwood sites where water and willow oak predominate with pine in cutover fuels.

Most terrace or "terrace-equivalent" sites, such as the Citronelle geologic formation in East Texas, are moderate to well-drained sites but support hardwoods that contribute fuels that are difficult to burn. Moderate to good pine stocking is desired to effect good burns. Burning chances are classed as moderate to poor, and available burning days become more limited as pine stocking decreases toward a minimum of 30 sq. ft. per acre.

3. Available Burning Days

Summaries of two-year, fuel-moisture and weather records indicate there are approximately 45 to 60 days per year, excluding Sundays, available for satisfactory burning in heavy to normal fuels in East Texas and 30 days where spring and fall burning can be done in light fuels.

Some 15 to 20 days may be expected for hazard-reduction burning in young pine plantations. Low air temperatures are needed to match other necessary fuel and climatic factors for safe and satisfactory burning.

Approximately 30 days are available for burning moderate to heavy fuels on steep slopes.

4. Man-Day Investments and Burning Costs

Research and demonstration burning experience on extensive areas has shown that 4 to 6 acres per man hour is a heavy workload for first

burns in normal to light pine-hardwood fuels where strip-headfires are used. As brush populations are reduced and access is increased, 10 to 15 acres per burner hour may be a reasonable goal. These levels may be equaled by backfire burning in normal pine-hardwood fuels during low-risk winter and spring seasons.

A 10- to 20-acre block is considered a maximum burning chance for one man using backfires under "average" day-to-day burning on first burns in heavy fuels under slash pine plantations. When ideal steady "dry norther" winds and low air temperatures prevail, several to many 10- to 20-acre blocks may be successively backfired by one or two burners to permit simultaneous burning. During third burns in this type strip-headfires may be used and 60 to 100 acres per burner day may be achieved.

When using experienced personnel at wage levels of \$1.00 per hour, burning costs may range from \$0.50 to \$1.00 per acre for hardwood-control backfires in slash pine plantations, \$0.30 to \$0.50 for backfires in normal pine-hardwood fuels and \$0.12 to \$0.50 per acre for strip-headfire burning in light to moderate fuels. Costs cover administration, equipment, fuel and labor.

Reported average costs for hardwood-control strip-headfire burning by a neighboring federal agency during 1959 was \$0.40 an acre. An industrial forestry group in Arkansas quoted an average cost of \$0.40 per acre for 9,000 acres prescribed-burn in 1959 (Clark 1960). The Crown Zellerbach Corporation has effected one or more burns on 107,000 acres of pine-hardwood and slash pine plantation fuels in East Louisiana at reported costs averaging 50 cents per acre per burn. Satisfactory hardwood control has been effected by 2 burns in some stands.

5. Effect on Range and Wildlife Habitat.

Observations of plant density and composition changes on forage sub-plots indicated that grasses and herbs showed a general increase after each of the three burns. Greatest increases were shown by panic grasses (Panicum spp.), Andropogon spp., lovegrass (Eragrostis spp.), and legumes. Grass increments under well-stocked pine-hardwood stands were generally too meager to be of material benefit to range interests. Modest increments of some benefit to cattlemen occurred behind burns on cutover areas. Good stands of andropogons, with good representation by both big and little bluestem, appeared after the third burn in slash pine plantation areas fenced 30 years against free-range grazing. Only a few scattered plants were in evidence under the smothering pine litter before the first burn.

When short-courses on prescribed-burning were first offered technicians, questions were raised about the effect of burning on wildlife habitat, particularly white-tail deer. Average height of understory hardwoods ranged from 9 to 12 feet at test establishment and 1.8 to 5.8 feet after the second burn. Lay's study (1956) of these plots lists such height reduction as one benefit to deer management. He reported burning did not materially affect total forage production and suggested evaluation for wildlife should be based on species composition.

Important forage weight changes reported the first year after a second

burn were yaupon down 68%, holly down 90%, yellow jessamine up 23%, viburnum up 515%, and herbaceous forage up 376%. A 1957 reference indicated that prescribed burning raised protein levels of forage through the second winter and phosphorus levels until the first winter. Spring burning was reported to improve browse quality more than fall or winter burning. For deer, it was indicated the benefits from burning increase as the understory succession moves away from optimum conditions of height and density. In summer, he recommended burning as often as it could be justified silviculturally, preferably in the spring (Lay 1957).

6. Relative Hardwood Control, Timing of Burns and Rotation Costs

In young well-stocked stands and plantations, first burns should be made early in the stand history. At age 10 to 15 years hardwood encroachment is usually well evidenced. Most stems are under 2 inches diameter and readily topkilled by 1 uniform burn. Maintenance burns can be made about every 10 years thereafter, just before thinning operations. Thus 6 or 7 total burns may be required per rotation, including 2 closely-spaced burns made just before the regeneration cut to reduce re-sprout thrift and prolong the subclimax condition. Total costs for all burns in the pine-hardwood fuels might range between \$2.40 and \$3.50 per acre. Comparable total burn costs in pine plantations might range between \$3.60 and \$4.50 per acre, assuming a 70-year rotation.

In light cutover fuels hardwood stems are usually of larger size and not readily topkilled by prescribed-burning. Three closely-spaced initial burns are considered necessary to effect all possible hardwood control. This should be stressed before planning for even-aged regeneration. In older stands the third burn may be timed just before expected fall of a good seed crop and thus also serve as a seedbed-preparation burn. In younger stands subsequent maintenance burns may be timed to control both re-sprout growth and prepare a pine seedbed, as needed.

ECOLOGICAL APPROACH PROSPECTS

Some industrial forestry groups have made remarkable strides in timing hardwood-control burns with shelterwood or seed-tree regeneration cuts. Figure 5 illustrates excellent even-aged loblolly regeneration established following hardwood-reduction burns and shelterwood cuts completed on extensive areas since 1953. Comparable results are reported in southern Arkansas where preparatory burns and seed-tree cutting established an even-aged shortleaf crop (Clark 1960). Other groups in Texas have effected one or two basic burns across extensive acreage in young stands or have embarked on a program of personnel training in prescribed-burning.

The move toward an ecological approach to silviculture appears significant. The turbulence that wiped away the Indian summer atmosphere offers, yet, faint promise of a zephyr that will help unfold a new era. Recent forest-soils symposiums and the formation of forest-soils councils is a promising sign. It may be here that the ecological view will assist in the interpretation and correlation of dynamic soil-plant-climatic relationships in future silvicultural problems.

Figure 5. Advance, even-aged loblolly pine regeneration in eastern Louisiana following hardwood-control prescribed burns and shelterwood cutting. (Courtesy: Crown Zellerbach Corporation, Southern Timber Division)

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FIRE RETARDANT TREATMENTS ON THE SANTA FE

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The annual fire loss statistics of the Fire Protection and Insurance Section of the AAR indicate under the designation of "Bridges, Trestles and Culverts' the following for the 5-year period 1954 to 1958:

Year	Number of Fires		Losses
1954	207		$ 729,518
1955	222		1,116,691
1956	196		930,235
1957	135		267,666
1958	179		576,256
	939		$ 3,620,366
	Average per fire	$3,855.55	

These averages are low, but it should be remembered that they represent only the actual loss of bridges from fire, and not the loss of time, delays and rerouting of traffic because a main line was blocked due to loss of a timber trestle from fire.

In this same period, the Santa Fe had 7 fires with a total property damage of $28,225.00, averaging $4,032.14 per fire.

Because we have approximately 128 lineal miles of timber trestles, we have been working on this problem of fire intermittently for many years, and actively since 1952.

To us on the Santa Fe, studies have shown that the timber trestle is our most economic bridge. Our division bridge forces are trained in this type of construction. Also due to experience in preframing and treating of timbers, it has been possible to receive maximum service life. Our timber grading requirements are high and these three factors add to a life expectancy for ballast deck trestles approaching 60 years, and for open deck, 55 years.

There are two problems involved in a program of fire protection such as this, namely: (1) protection of bridges now in track; (2) protection of new construction.

For the bridges now in track the most promising method is a surface treatment with a grease-like material that has phosphorus present in the form of triaryl phosphate. This material penetrates into the wood after a short time (2 to 6 weeks) to give seemingly adequate protection. Retentions are given in Table 3.

For fire protection of new structures, we are currently using triaryl phosphate in a 50/50 creosote-petroleum treating solution. We believe

that a retention of 0.1 lb/cu.ft. of active phosphorus will give adequate protection.

Figures 1 through 4 illustrate the typical full-scale test. In the first illustration, tumble weeds are placed ready for ignition. The Douglas fir timbers were treated to refusal with 0.91% phosphorus as triaryl phosphate in a creosote-petroleum mixture.

Figure 2 shows the peak fire which occurs within about 45 seconds from the start of the test. Temperatures at this time average approximately 1700°F taken at a point immediately under the trestle deck.

Figure 3 shows the fire 8 minutes from the start of the test, the characteristically sharp decrease in flaming had occurred although burning persisted in protected locations.

Figure 4 illustrates the elevation and section of our end panel replica for the fire test.

Figure 5, again illustrating the effect of triaryl phosphate, compares time-temperature curves from test fires on trestles of like design. The dotted line represents a treatment using a 20% Arban solution in 50/50 creosote-petroleum mixture. (Net gain in piles: 15.40 lbs/cu.ft., or 0.22 lb of phosphorus per cu. ft. Net gain in lumber: 6.70 lbs/cu.ft., or 0.0938 lbs of phosphorus per cu.ft.)

The solid line represents a treatment of $13\frac{1}{2}$% ET-204 (Arban 70) in 50/50 creosote-petroleum mixture. (Net gain in piles: 6.68 lbs/cu.ft., of 0.063 lbs of phosphorus per cu.ft. Net gain in lumber: 5.28 lbs/cu.ft., or 0.0499 lbs of phosphorus per cu.ft.)

Figure 6, also illustrating the effect of triaryl phosphate, compares time temperature curves obtained from test fires on newly-treated trestles of like design. The dotted line represents a treatment of $13\frac{1}{2}$% Arban 70 in 50/50 creosote-petroleum mixture. (Net gain of piles: 14.44 lbs per cu.ft., or 0.136 lbs of phosphorus per cu.ft. Net gain of lumber: 10.39 lbs/cu.ft., or 0.098 lbs of phosphorus per cu.ft.)

The solid line represents a treatment of $13\frac{1}{2}$% ET-204 (Arban 70) in 50/50 creosote-petroleum mixture. (Net gain in piles: 7.97 lbs/cu.ft., or 0.075 lbs of phosphorus per cu.ft. Net gain in lumber: 11.24 lbs/cu. ft., or 0.106 lbs of phosphorus per cu.ft.)

Table 1 illustrates the typical analysis of Seguro oil used in add mixtures with creosote, and Table 2 is the typical analysis of creosote used in add mixtures with the Seguro oil.

The effectiveness of other compounds has been studied. Laboratory tests indicated that a chloroalkyl phosphate and a bromoalkyl phosphonate show three to five times the effectiveness of the triaryl phosphates. However, the triaryl phosphates performed much better in rigorous field tests than in the lower temperature laboratory evaluations. This fact emphasizes the point of Schuyten _et al._, that the fire retarding agent must "be present or produced from its precursor ..." at burning temperatures.

Two haloalkyl phosphorus compounds were tested favorably in a grease-like surface application in which the material was carried into the wood. These materials have the necessary properties such as good solubility in oils, low solubility in water, low vapor pressure at ambient temperatures, and relatively low toxicity. However, they have marginal stability at treating temperatures in the presence of a small amount of water and as yet their costs are high.

Figure 1. Full-scale trestle replica test ready for ignition. Douglas fir timbers treated with 0.91% phosphorus as triaryl phosphate in a creosote-petroleum mixture.

Figure 2. Same as Figure 1, showing peak fire 45 seconds after ignition. Temperature reached 1650°F or higher.

Figure 3. Same as Figure 1 eight minutes after ignition. Some local burning still persists in protected pockets. Char is about 1/4 inch deep.

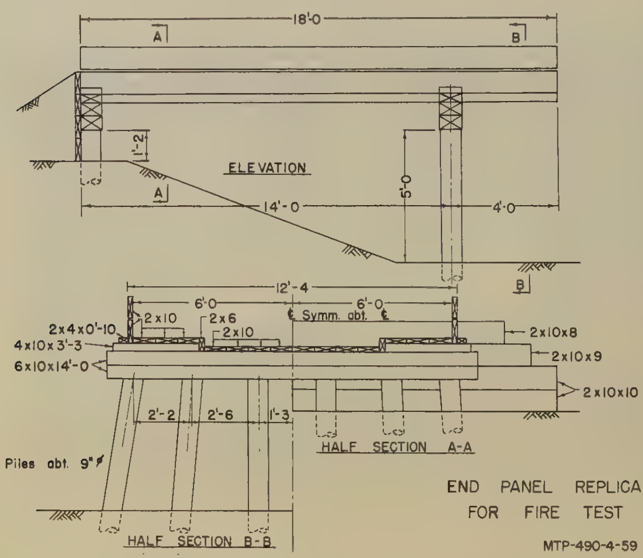

Figure 4. Plan and elevation of end panel replica for fire test.

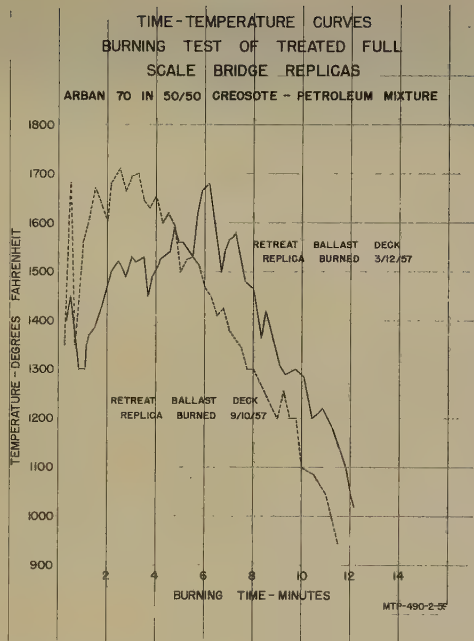

Figure 5. Time temperature curves of Douglas fir timbers retreated with creosote-petroleum mixtures containing 1.4% and 0.95% phosphorus as triaryl phosphate to obtain .159 and .056 lbs of phosphorus per cu. ft.

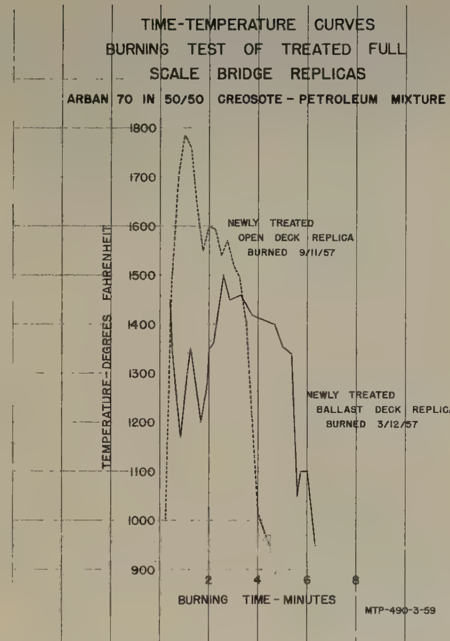

Figure 6. Time temperature curves on newly-treated Douglas fir timbers with a creosote-petroleum mixture containing 0.95% phosphorus as triaryl phosphate to get retentions of .117 lbs per cu. ft. as represented by the dotted line, and .090 lbs. per cu.ft. as represented by the solid line.

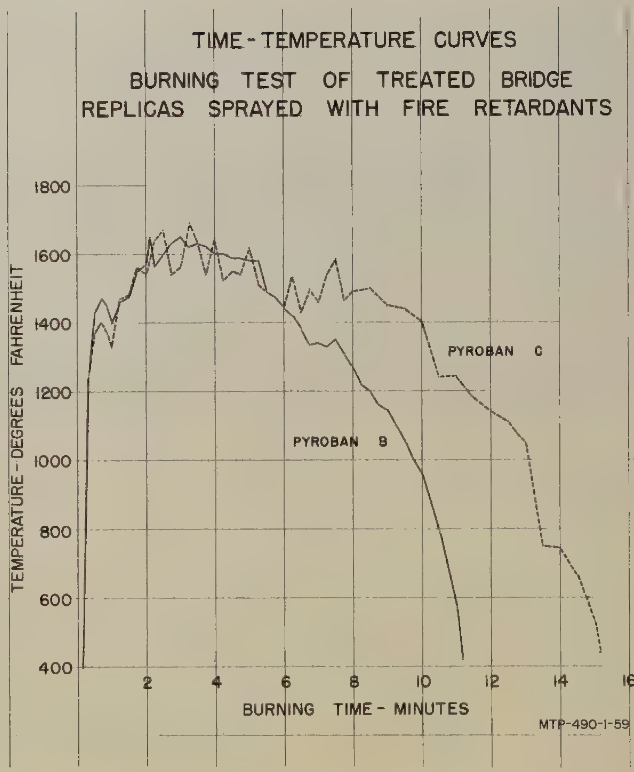

Figure 7. Time temperature curves on treated timber replicas sprayed with Pyroban C (a chloroalkyl phosphate) [dotted line] to a thickness of .07 in. Average retention of .166 lbs per cu. ft. phosphorus in outer 1/4 in. The solid line represents a coating of 1/16 in. of Pyroban B (a bromoalkyl phosphonate). Average retention is .268 lbs phorphorus per cu. ft. in outer 1/4 in.

Figure 7 illustrates the effect of treatment with a bromoalkyl phosphonate (Pyroban B) and the chloroalkyl phosphate (Pyroban C). The Pyroban C was sprayed October 6, 1959 on the replica to an average thickness of .07 in. The Pyroban B was also sprayed October 6, 1959 to an average thickness of 1/16 in. Table 3 illustrates the retentions of these materials from various locations sampled.

Early testing showed less fire hazard on untreated timbers than treated timbers. Studies showed that the higher the retention of preservative oils, the greater the hazard, for the fire hazard increases as the fuel is

Table 1. Typical specification of seguro oil used in trestle replica test.

Distillation (corrected for elevation)			
Up to 315°C	4.8%	Specific Gravity 100/60°F.	0.962
315 to 355°C	12.6	Water content	0.5%
Residue	82.0	Flash point PMCC	115.5°C
Loss	0.6	PMOC	163.0°C

Table 2. Typical specification of creosote used in trestle replica test.

Distillation (corrected for elevation)			
		Specific gravity 38°C/15.5°C	1.071
Up to 210°C	1.3%	Water content	1.3%
210 to 235°C	4.7	Coke residue	0.7%
235 to 270°C	26.4	Flash point PMCC	196.0°F
270 to 315°C	24.7	Insoluble in Benzol	.08%
315 to 355°C	23.0		
Residue	19.1	Specific gravity of fractions	
Loss	0.8		
		A (235 to 315°C)	1.036
		B (315 to 355°C)	1.114

Table 3. Retentions of Arban 86 in pounds per cubic foot.

Grease	Outer 0.25 inch	Second 0.25 inch	Third 0.25 inch	Position in Bridge Replica
Pyroban B	1.77	0.81	0.65	Bottom of fir decking (8 bds.)
Pyroban C	1.46	0.11	0.09	" " "
Pyroban B	1.87	0.33	0.32	Inside fir cap
Pyroban C	0.83	0.22	0.20	" " "
Pyroban B	4.32	1.50	1.22	No.5 Piling - no bleeding
Pyroban B	4.51	1.20	1.20	No.2 " " "
Pyroban C	2.68	0.64	0.30	No.2 Piling " "
Pyroban C	1.31	0.39	0.48	No.1 Pine Piling - dry side
Pyroban C	1.37	0.07	0.05	No.1 " " - bleeding side

increased. From this, we believe that an increase in the ratio of fire retardant to oil is necessary as the total oil is increased.

We also noted that the most persistent flaming always occurred in protected locations where entrapped heat could cause volatile materials to burn above the wood surface and away from the phosphate additive, thus indicating a need for a flame-controlling agent.

On the basis of these investigations, we have concluded that phosphorus as triaryl phosphate contributed materially to reduction of fire hazard. Phosphorus-halogen mixtures in the proper ratio to preservative solutions will improve fire control. It has also been shown that increased retention of preservative oil solutions increases fire hazard.

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SPECIFIC GRAVITY OF RED PINE AS RELATED TO STEM AND CROWN-FORMED WOOD[1]

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Introduction

It is commonly recognized that where strength is important high density wood is superior to low density wood. Pulp manufacturers have found that high density pulpwood produces a higher yield of pulp than does low density pulpwood. For these reasons there have been numerous efforts to determine the environmental factors which affect wood density with the ultimate objective of recommending silvicultural practices which will result in the production of higher density wood.

One of the factors which is frequently studied in relationship to wood density is rate of growth. Recent studies with conifers indicate that within certain limits of ring width there is an inverse relationship between growth rate and wood density. Hale and Prince (1940) found that in spruce and fir in Canada, over an extensive range of growth rates, rapidly grown wood was light and slowly grown wood was heavy. On the other hand, Paul (1930) found that in conifers the wood produced at an intermediate growth rate was usually heavier. In old growth southern pine the outer portions of the tree which showed narrow rings had wood of low specific gravity, and the central portion of the bole where the growth rate was intermediate had wood of high specific gravity. In second growth trees wood of low density was found in the wide rings in the central portion of the bole.

Other investigators, notably Spurr and Hsuing (1954) and Larson (1957) discounted the effects of rate of growth. Larson found that in slash pine the growth rate exerted a negligible effect on both the specific gravity and the percentage of summerwood, and that for all practical purposes it could be ignored. Spurr and Hsuing found in their study of conifers that neither ring width nor stem diameter accounted for more than a minute percentage of the variations in specific gravity.

Variations in specific gravity within a tree stem have been found to correlate very closely with the variations in proportion of summerwood

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[2]The research work presented in this paper was conducted at Iowa State University in partial fulfillment of the requirements for a Master of Science degree. The author wishes to express his appreciation to his major professor, Dr. D. W. Bensend, for his help in the planning and carrying out of the project.

to springwood. Rochester (1933) reported that in red pine, jack pine, white spruce, and balsam fir there is an increase in the specific gravity as the proportion of summerwood increases. Pillow (1951) reported that this was primarily due to the consistently higher density of the summerwood as compared to the springwood. Larson (1957) found that the percentage of summerwood accounted for about 60% of the total variation in the density of slash pine.

The density of wood within a given cross-section of a coniferous stem has been found to increase from the pith to the cambium almost without exception. Paul (1957a, 1957b) working with 14 to 37-year-old red pine found that the increase in specific gravity away from the pith was greater in the lower portions of the tree due to the central core of juvenile wood that is characterized by wide annual rings and a low percentage of summerwood. At the 400 inch level juvenile wood made up almost the entire core, but near the ground only the wood in the inner core was juvenile wood whereas the outer sheath resembled mature wood. Thus the apparent gradient in density from the pith outward was more evident closer to the ground.

Wood density has also been found to vary longitudinally in the stem. Trendelenburg (1939) reported a zone of light wood running up the center of the tree bole and becoming broader toward the top. Contrasted to this was a zone of heavier wood constituting the outside shell of the lower bole and decreasing in density with increasing height. Spurr and Hsuing (1954) made a study of density variations and also concluded that specific gravity decreased with increasing height.

Several studies have been made investigating the relationship of cardinal direction to specific gravity but in only one case have any positive results been found. Nylinder (1953) in a study of Norway spruce observed that in the outer sapwood the oven-dry density values on the north side of the bole had a slightly higher mean than did those values observed from the south side of the tree.

The age-density theory has been presented by Turnbull (1937) who worked with Pinus taeda in South Africa. He concluded from his study of 30-year-old stock that the density of wood produced in a particular season was not determined by rate of growth, but that it was proportional to a function of age. He found that density continued to increase steadily from the pith outward regardless of increases or decreases in ring width. Other investigators, however, have demonstrated that a less positive relationship exists with age. Paul (1957b) found that the increase in density of red pine was not completely consistent with increases in the age of the wood, but that there was a general tendency for that relation to hold true. Pillow (1954) showed that there was a poorer correlation of density with age than with either the percentage of summerwood or the rate of growth.

In his study of slash pine Larson (1957) found that the specific gravity was directly correlated with the percentage of summerwood. Furthermore, the percentage of summerwood increased with increasing June and July rainfall and decreased with increasing January and February precipitation. Jayne (1958) in an investigation of plantation grown red pine concluded that it is highly probable that environmental characteristics such as seasonal fluctuations of soil moisture and the soil texture are closely associated with the density of wood produced.

Paul and Marts (1931) have done extensive work on the relation of site conditions to the production of dense wood. In work on longleaf pine they found a fairly close correlation between the soil water supply on deep sandy soils and the formation of summerwood. They concluded that maintenance of forest soil conditions in a manner which would promote the retention of available water would result in both a greater rate of growth and the production of denser wood than could be obtained under poor soil conditions.

The size of the tree crown and its relation to density of the wood is a factor which cannot be considered alone. There are many interactions involved such as stand density, age of the trees, site conditions, silvicultural practices and characteristics peculiar to a given species which must also be considered. Paul's conclusions (1930) bear this out. He observed that in the early years of growth in coniferous stands the size of the individual tree crown appears to be the principal factor determining the specific gravity of wood. In general a smaller crown results in higher density wood. Trendelenburg (1935) concluded that there was an optimum crown size which gave a good balance between springwood and summerwood formation and specific gravity of the wood. Paul and Smith (1950) found that as long as the green crown persisted along the length of the tree the wood produced resembled juvenile wood in that it had a high springwood percentage, but as the green crown moved upward, through natural pruning, there was a gradual increase in the density beginning in the lower part of the bole.

Procedure

In order to investigate a major hypothesis that stem-formed wood is heavier than crown-formed wood, five 36-year-old plantation grown red pine (*Pinus resinosa* Ait.) were selected from a small stand in central Iowa. The pruning and thinning history of the stand is known and the trees were chosen on the basis of the similarity of their growing conditions, crown size, total height, length of live crown, diameter at breast height, and site and soil conditions. Of the five trees, four were free from visible defects and selected for study; one was rejected when it was found to contain compression wood.

Before each tree was felled the north face was indicated by chalk mark from the ground line to a height of about eight feet. The trees were then cut as close to the ground as possible. The stump height from the ground line was recorded and all subsequent heights in the tree were measured and marked with reference to the ground line. The chalk line was extended the full length of the tree and both total height and height to the first living branch as indicated by the foliage were recorded.

Sample discs 0.2 foot thick were chosen from each tree at approximately two foot intervals beginning at the stump. The height from the ground line to the top of each sample disc was measured and placed on an identification tag which also showed the tree number and cardinal direction. These tags were stapled to the discs. Over the entire length of the stem it was possible to distinguish overgrown branch whorls by the disruption in the bark scales. Discs falling on or just beneath the whorls were shifted above the whorls to avoid compression wood (Pillow

et al., 1936). After the discs had been selected and tagged up to a one inch top diameter, the trees were bucked into six foot sections to facilitate transportation to the laboratory.

At the laboratory each marked disc was cut in numerical sequence. Diametrical segments one-half inch wide were marked for cutting as each disc was removed from the bolt. These segments were a half-inch wide through the center of the discs from the north periphery to the south periphery. The segments were cut from the disc and then recut into the desired size of one-half inch by one-half inch.

These segments were then stored in the green condition under distilled water in a refrigerated room until the ring width measurements could be made. These measurements were made with a steel rule to the nearest hundredth of an inch using a binocular microscope. Measurements were made on both the north and south halves of the segments. The specimens were than allowed to air dry.

It was further necessary to cut the specimens as shown in Figure 1 because ring width comparisons with specific gravity for successive five year increments were desired. The wedges were cut so that each five year increment, as well as each annual ring, represented equal arcs of their own circles (Millar and Malac, 1955). These wedge shaped specimens were allowed to dry after cutting and were then placed in dacron bandoliers with an identifying tag. The purpose of the bandoliers was to facilitate loading the specimens in the Soxhlet extractors. Treatment with pure benzene in the extraction columns (Figure 2) removed the resins and other benzene soluble extractives contained in the samples which would be a source of error in specific gravity determinations.

The specific gravity of the 790 samples was determined by the maximum moisture content method developed by Smith (1954). The apparatus used for the saturation of the samples consisted of a motor driven vacuum pump which evacuated the air from the desiccator jar filled with the samples, a distilled water supply for injection into the desiccator under vacuum, and a cycling mechanism which alternately applied atmospheric pressure and a water aspirated vacuum to the immersed samples (Figure 3). When the samples were thoroughly saturated the weight was taken on a direct reading Sartorius Selecta automatic balance. The specimens were then oven-dried to a constant weight and again weighed. The specific gravity was calculated by the maximum moisture content formula:

$$G_f = \frac{1}{\frac{Mm - Mo}{Mo} + \frac{1}{Gso}}$$

where

G_f = specific gravity based on the green volume

Mm = mass of the water saturated wood in grams

Mo = oven-dry weight of the wood sample in grams

Gso = specific gravity of wood substance comprising the cell walls (1.53).

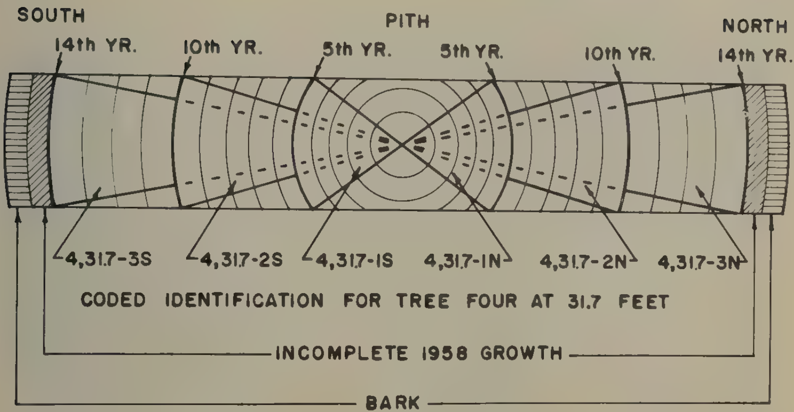

Figure 1. Diagram of a 14 year segment. The solid lines represent the lines of cutting and the broken lines represent projected radii. The symbols show the method of coding each wedge.

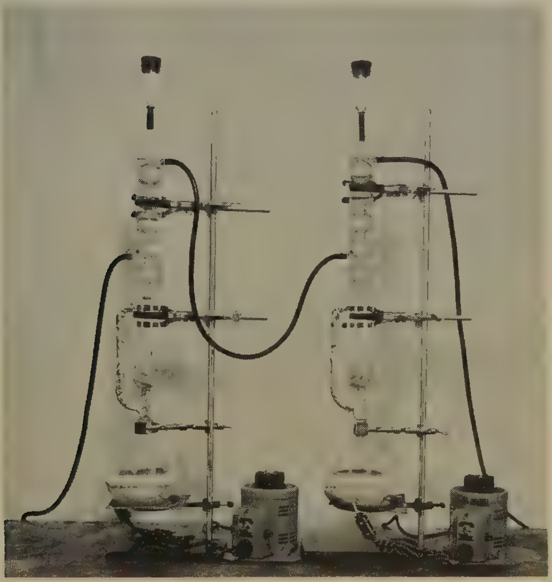

Figure 2. The extraction columns with the condensors in tandem. The bandoliers and samples are in the extraction chamber, and the feed tubing from the boiling flasks is wrapped with aluminum foil.

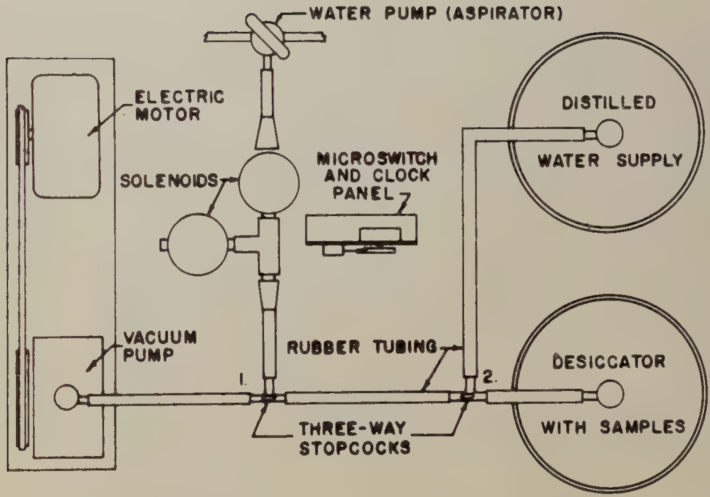

Figure 3. Schematic diagram of the saturation apparatus. When the pump was in operation valves 1 and 2 were open to provide a direct line from the pump to the desiccator. Water was introduced by opening stopcock 2 while a vacuum existed in the desiccator. The cycling mechanism was operable when stopcock 1 was open to the solenoids and closed to the pump and stopcock 2 was open to the line and closed to the water supply.

Each segment was then classified into stem-formed or crown-formed wood by an examination of the branch whorls throughout the length of the stem. As all specific gravity discs were cut just above the whorls, their annual rings were assumed to be the same as those of the immediately adjacent wood in the branch whorls. The formation of the wood in the whorl discs was determined by finding the annual ring at which the knot changed from intergrown to encased. All rings that were intergrown with the knot were formed while the whorl was in the living crown. Therefore these rings were designated crown-formed wood and the remainder stem-formed wood (Figure 4).

Climatic data were taken from local weather summaries, and the average monthly precipitation and the number of continuous frost-free days during the growing period were calculated for the years of wood formation of each of the samples. In addition to these data, age of the tree when the wood was formed, age as measured by ring count from the pith, height in the tree and ring width were determined, and a correlation analysis was run on an I.B.M. "650" automatic computer.

Figure 4. A typical whorl disc showing a partially encased knot. The first twelve annual rings from the pith are intergrown with the knot and constitute crown-formed wood. The remaining ten annual rings are stem-formed wood.

Results and Discussion

The Specific Gravity of Stem-formed and Crown-formed Wood

The longitudinal section of tree No. 1 is presented in Figure 5. This diagram shows the area of the stem-formed wood, the area of the crown-formed wood, and successive five year increments of growth as measured from the cambium inward. Five zones of varying specific gravity are also shown. In this tree the lowest three categories of specific gravity are in the area of the crown-formed wood and the heaviest two in the area of the stem-formed wood. In the other three trees the trend was similar but not as striking, with a narrower range of densities. A summary of the mean specific gravities is presented for several groupings in Table 1.

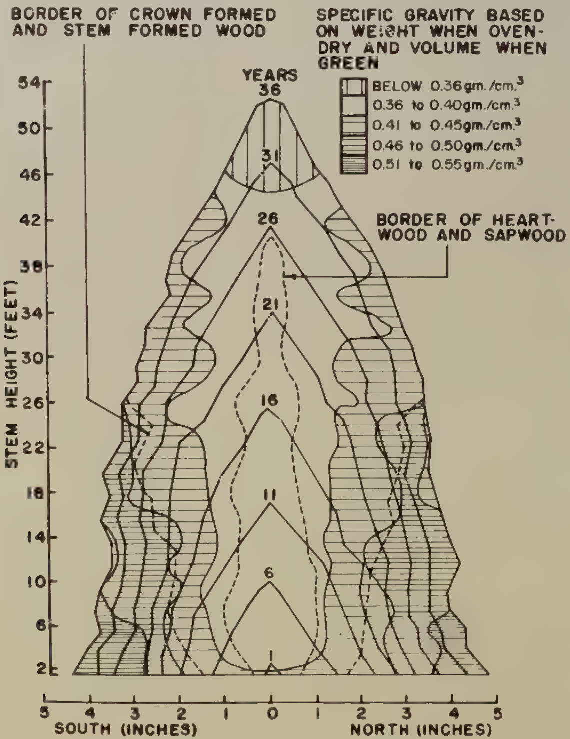

Figure 5. Diagram of the longitudinal section of tree No. 1. The reconstruction of the tree was made from the data on each segment in the tree. It is oriented from north to south through the pith. Note the comparatively close agreement between the specific gravity zones and the border of stem-formed and crown-formed wood.

Table 1. A summary of the specific gravity averages for all trees.

Position in the tree	Tree Number one	three	four	five	All trees
North crown	0.4072	0.3181	0.3011	0.3024	0.3355
South crown	0.4049	0.3139	0.3007	0.3002	0.3336
North stem	0.4772	0.3466	0.3097	0.2961	0.3632
South stem	0.4856	0.3397	0.2958	0.2866	0.3569
Total crown	0.4060	0.3160	0.3009	0.3013	0.3345
Total stem	0.4814	0.3431	0.3027	0.2913	0.3600
Total north	0.4349	0.3304	0.3051	0.3004	0.3466
Total south	0.4362	0.3251	0.2984	0.2959	0.3430
All wood	0.4356	0.3277	0.3017	0.2981	0.3448

Tests of the significance of the differences between north stem and crown-formed wood and between south stem and crown-formed wood were made (Snedecor, 1946). In each case stem-formed wood was found to be significantly heavier than crown-formed wood at the 0.1% confidence level. These calculations were based on the mean density of the crown-formed wood computed from all four trees as compared to the stem-formed wood from all four trees. There was no significant difference in mean specific gravity between all wood formed on the south side of the tree and all wood formed on the north side of the tree.

Specific Gravity and Ring Width without Regard to Stem and Crown-formed Wood

A summary of ring width averages is presented and the relationship of specific gravity to age, as measured from the pith, and average ring width is shown in Table 2. The trend of increasing specific gravity with decreasing ring width is misleading in trees 1 and 3 in that these data were arranged without regard to stem-formed and crown-formed wood. Ring width in itself decreased from the pith outward; and specific gravity (without regard to the stem or crown) increased from the pith outward in trees 1 and 3. Actually, this may not be indicative of a valid relationship between specific gravity and ring width. Trees 4 and 5 were similar to trees 1 and 3 (Table 2) in that they also showed a decreasing ring width from the pith outward; but they were different in that they did not show the same definite pattern of increasing specific gravity outward from the pith. It was further apparent after plotting all individual observations of specific gravity over ring width that there was little evidence of a relationship which would hold true for all the trees studied. In tree 1 an inverse relationship of density to ring width was indicated, while in tree 5 a positive relationship was apparent. The other two trees showed no relationship.

Table 2. Specific gravity and ring width averages of all segments of equal age as measured from the pith outward over the entire height of the trees.

Tree number	Years of segment formation	Number of segments	Average specific gravity	Average ring width in inches
Tree one	0 - 5	50	0.3676	0.2312
	6 - 10	46	0.4165	0.1645
	11 - 15	40	0.4406	0.1133
	16 - 20	34	0.4690	0.0956
	21 - 25	24	0.4828	0.0850
	26 - 30	16	0.4942	0.0938
	31 - 35	10	0.4996	0.0940
	36*	2	0.5208	0.1050
Tree three	0 - 5	42	0.3255	0.1826
	6 - 10	38	0.3079	0.1781
	11 - 15	34	0.3150	0.1174
	16 - 20	28	0.3337	0.0842
	21 - 25	22	0.3586	0.0868
	26 - 30	16	0.3310	0.0694
	31 - 35	6	0.3464	0.0800
	36*	4	0.3948	0.0950
Tree four	0 - 5	44	0.3124	0.1798
	6 - 10	42	0.2947	0.1755
	11 - 15	34	0.2818	0.1291
	16 - 20	28	0.3028	0.0957
	21 - 25	22	0.3085	0.0823
	26 - 30	18	0.3045	0.0594
	31 - 35	10	0.3046	0.0570
	36*	2	0.3257	0.0650
Tree five	0 - 5	40	0.3134	0.1852
	6 - 10	38	0.2953	0.1918
	11 - 15	32	0.2909	0.1469
	16 - 20	26	0.2989	0.0962
	21 - 25	20	0.2970	0.0670
	26 - 30	14	0.2831	0.0400
	31 - 35	6	0.2810	0.0400
	36*	2	0.3210	0.0500

* Incomplete 5 year segment containing only 1957 growth ring.

Specific Gravity and Height without Regard to Stem and Crown-formed Wood

When the specific gravity observations were tabulated according to vertical position in the tree, the data for tree 1 showed decreasing specific gravity from the base upwards. In tree 3 the same trend was evident, but it was not as pronounced. Thus, there is some evidence that specific gravity does decrease with increasing height in the stem, but as in the case of ring width and specific gravity this is not a true representation of a relationship between height and specific gravity because no attempt was made here to separate stem and crown-formed wood.

The Effect on Specific Gravity of several Variables when Stem and Crown-formed Wood are Separated

The results of a correlation analysis are presented in Table 3. This analysis was made to determine the relative importance and effect on specific gravity of each of several variables considered individually. The specific gravity data were combined and stratified into four categories for this analysis. These were: (1) all wood formed in the north half of the living crown, (2) all wood formed in the south half of the living crown, (3) all wood formed in the north half of the stem, and (4) all wood formed in the south half of the stem. The simple correlations resulting from an analysis of these separated data and each of the several variables are quite revealing. In every case the simple correlation coefficient of a particular variable considered with specific gravity was extremely low. This is not in contradiction to previous interpretations in this study in which there appeared to be an increase in specific gravity with increasing height and decreasing ring width, because in the previous interpretations stem and crown categories were ignored. In the present analysis all data were categorized as listed above. This categorization resulted in low individual correlations between the variables used and specific gravity giving further evidence that the effect of the living crown is predominant in controlling specific gravity, regardless of height in the tree or rate of growth. The combined effect of the variables listed in Table 3 expressed as the multiple "R" suggest that much of the total variability of specific gravity in the crown was accounted for. In both the north and south crown-formed wood the multiple correlation coefficient was .662. Thus about 43% of the variation was contributed by the combined effect of the variables studied. If summerwood percentages had been included in the study it is believed that a much higher percent of the variation could have been accounted for.

The multiple "R" expressions for the north stem and south stem were .443 and .429 respectively. Thus the combined effects of all the variables considered accounted for only about 19% of the variability in the density of the stem.

It was interesting to note that the average September precipitation had the highest correlations with specific gravity in the crown, whereas in the stem, the June plus July precipitation was the highest. The simple correlation coefficients ("r") were .066 and .013 in the crown and .162

Table 3. Simple correlations of all variables on specific gravity.

Variable	X_1	X_2	X_3	X_4	X_5	X_{10}	X_{12}
A. The north crown-formed wood							
Y	.092	-.004	.008	-.071	.123	.066	.007
B. The south crown-formed wood							
Y	.069	-.057	-.050	-.127	-.061	.113	.008
C. The north stem-formed wood							
Y	.060	-.058	.256	-.039	.019	-.022	.162
D. The south stem-formed wood							
Y	.112	-.031	.245	.035	-.064	-.043	.125

X_1 distance from the pith by segment number.
X_2 height from the ground line in feet.
X_3 average ring width in hudredths of an inch.
X_4 average age of the tree when the wood was formed.
X_5 average number of frost free days during the growing seasons of the five year period corresponding to the segment years.
X_{10} average September precipitation during the five years of segment formation.
X_{12} average June plus July precipitation during the five years of segment formation.
Y specific gravity of the five year growth segments.

and .125 in the stem. These values are very low indicating that precipitation alone probably accounts for only a small part of the variation in specific gravity.

In the first analysis of specific gravity and age, as determined by ring count from the pith, there appears to be an increase in specific gravity with increasing age in trees 1 and 3 (Table 2). In trees 4 and 5 no definite increase is evidenced. In all trees, ring width decreased from the pith outwards so this does not enter the discussion as a confounding variable. That the four trees do not show the same trends of specific gravity with age does not in itself negate the conclusions of other investigators who found that specific gravity increased with increasing ring count from the pith, but it does suggest that there is more than just this one factor to consider.

The same is true in the second analysis where specific gravity was related to the age of the tree when the wood was formed. In each of the categories used in the correlation analysis (Table 3) the simple correlation coefficients of specific gravity (Y) with age of the tree when the wood

was formed (X_4) were all very low. This indicates that there is either an interaction of this variable with another or that something else is masking the effect of this variable. Thus it is true here also that age of the tree when the wood was formed does not in itself account for much of the variability in specific gravity.

In this investigation there was no indication that the average number of frost free days, calculated from the last day of freezing temperatures in the spring until the first day of freezing temperatures in the fall, had any effect on specific gravity either in the stem or in the crown-formed wood.

If the trees are studied individually, trees 1, 3 and 4 show heavier stem-formed wood than crown-formed wood. In tree 5 the specific gravity of the stem-formed wood was 0.291 whereas that of the crown-formed wood was 0.301. It should be remembered that not all trees have heavier stem wood but that when the specific gravity decreases with height or distance from the pith it can be largely accounted for on the basis of whether the wood was formed on the bole within the living crown or below the crown. Stem-formed wood on a stand basis would no doubt be heavier than crown-formed wood, even though there may be some trees of the stand which do not have heavier stem wood.

The important fact is that each of the individual variables appears to affect specific gravity according to whether the relationship is associated with the stem or the crown-formed wood. Categorizing the samples into stem-formed and crown-formed wood to a large extent serves to mask the effects of most of the other variables, as well as to change the amount of interaction between the variables. Thus, it appears that the wood density is more directly related to some effect of the crown than to any one variable or combination of variables. This does not differ appreciably from the results of other investigators, but it does reveal that the cause and effect relationships presented may very well have been mistaken.

Summary and Conclusions

Four red pine trees from a 36-year-old plantation near Ames, Iowa, were examined to determine how specific gravity varies with position in the tree depending on whether the wood was formed on the bole within the living crown or below the living crown. Other variables studied to determine their effect on specific gravity were height of the wood in the stem, age by ring count from the pith, age of the tree when the wood was formed, cardinal direction, seasonal precipitation, and length of the growing season. The specific gravity of all samples was calculated by the maximum moisture content method after the removal of all benzene soluble extractives. A correlation analysis was made to determine the effect of each variable on specific gravity. The following conclusions were reached:

1. Stem-formed wood is significantly heavier than crown-formed wood.

2. When wood density specimens are sorted into stem and crown-formed wood the following variables show a very low correlation with specific gravity:

a. Ring width or rate of growth.
b. Distance from the pith or age by ring count from the pith.
c. Height of wood in the tree.
d. Total age of the tree when the wood was formed.
e. Seasonal precipitation averages.

3. When wood density specimens are not sorted into stem and crown-formed wood the following relationships exist:

   a. There is no constant relationship between specific gravity and rate of growth or ring width.
   b. Specific gravity tends to increase with increasing distance from the pith.
   c. Specific gravity decreases with increasing height.

4. There is no relationship between specific gravity and cardinal direction.

5. Specific gravity of the wood is not related to the number of frost free days in the growing season.

6. Whether wood is formed in the stem or in the crown is a major factor in determining specific gravity, but it does not account for all variation thus indicating that further study with the inclusion of summerwood percentages of the annual rings is necessary.

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A CONSUMER PREFERENCE STUDY OF CHARCOAL IN CENTRAL IOWA[1]

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The manufacture and marketing of charcoal have been proposed as a means of utilizing some of Iowa's low quality native hardwood timber. There is evidence to indicate that markets for charcoal are actually becoming more important both nationally and in Iowa, primarily because of increased domestic use in outdoor cooking. According to a recent U.S. Forest Service (1957) report, charcoal production in 1956 amounted to 264, 990 tons (somewhat above production in 1955 and other post-war years). It is estimated that about one-half was used for picnics, outdoor cooking at home, and by restaurants and dining cars. Industrial use accounted for 35 to 40%, and the remaining charcoal was used for a variety of purposes, including tobacco curing, poultry feed, and water purification.

Based on the study, "Retail Marketing of Charcoal in Iowa," conducted by the Forestry Department of Iowa State University in 1956, Iowans consumed an estimated 1, 461, 000 pounds of charcoal for domestic purposes in 1955. Production of charcoal within the state is practically nonexistent, hence virtually this total volume was imported in the form of briquets from producing areas in the South, East, and North.

Charcoal production costs using Iowa timber are not generally known, though some information is becoming available. Without access to briqueting plants in Iowa or neighboring areas, the small producer would have to sell lump charcoal. The financial investment and raw material needed to build and operate small charcoal kilns are small, while similar requirements for briqueting plants are high.

Most of the charcoal currently used for domestic purposes in Iowa is in briquet form. Furthermore, wholesalers and retailers of charcoal believe that consumers prefer briquets. However, because some distributors have never handled charcoal in any other form, it is unlikely that they can objectively evaluate consumer preference between briquets and lump charcoal.

Whether or not lump charcoal can eventually be successfully marketed in competition with firmly established briquet charcoal will depend upon consumer choice between these forms. Obviously this choice cannot be made unless consumers can compare lump and briquet charcoal in use.

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Furthermore, before a truly satisfactory lump charcoal product can be marketed, charcoal producers need to find out just what kind of charcoal product consumers really prefer.

Conducting more marketing research to discover consumer preferences with regard to a particular product has been discussed and strongly recommended in a recent article by Gregory (1957). Others (Brundage, 1959; Hughes and Huey, 1958; Miller and Brundage, 1959; Zaremba, 1959) have reported consumer preference studies during the last few years. There is undoubtedly much to recommend a consumer approach to marketing or product research if, as seems obvious, markets exist primarily to satisfy consumer wants. As a matter of fact, the market success or failure of a given product, particularly if there are also good substitute commodities available, depends upon consumer preferences. No producer or manufacturer can logically overlook the need for discovering what consumers prefer with respect to the product he manufactures. If his goal is maximization of profits and expansion of sales, this is as important as production at minimum cost.

Much marketing research in forestry has been producer-oriented rather than consumer-oriented, however. The marketing of briquet charcoal is a case in point. Briquets have been marketed without benefit of investigation as to consumers' desires regarding this product; i.e., marketing is producer-oriented and supposedly is aimed primarily at increasing returns to producers of charcoal. It does not necessarily follow that charcoal should be marketed in this form, or that producers are marketing the most profitable product or combination of charcoal products.

To throw some light on this problem, the Forestry Department of Iowa State University undertook a small scale, consumer-oriented charcoal preference study in 1957. The over-all objective was to explore consumer preferences for briquet and lump charcoal, at least in small central Iowa towns. At the same time, an attempt was made to collect related information such as length of consumer experience with charcoal, average amount of charcoal used per year, market availability of each form of charcoal, the desirable as well as undesirable physical characteristics of briquet and lump charcoal in use, and the probable influence on consumer preference of price differentials between lump and briquet.

How the study was conducted

A total of 18 retailers—8 in Ames, 5 in Perry, 4 in Nevada, and 1 in Grand Junction—who had participated in the 1956 retail marketing study agreed to cooperate. These dealers were asked to give each purchaser of ten or more pounds of briquet charcoal a card which could later be redeemed for a free ten-pound bag of Iowa-produced lump charcoal provided by the Forestry Department of Iowa State University. Dealers were supplied with free bags of the lump charcoal in 4 different size grades: (1) small; (2) medium; (3) mixed; (4) ungraded. Recipients of the free charcoal were asked to use it, and later in the fall of the year each was contacted personally, if possible, or by phone for an interview; a few responses had to be obtained by mail questionnaire. Of a total of 283 participants, 212, or 75%, answered the questionnaires either fully or in part.

The major findings

Although most respondents had some experience with charcoal briquets (96%), only 25% had at some time used lump charcoal. A majority of the respondents (57%) stated that they had been using charcoal for cooking one or two years. Only 5% had been using charcoal as long as 10 years. The information collected suggests that the average number of charcoal users per year in these towns has approximately doubled every three years. The average amount of charcoal used in 1956 was about 55 pounds, but some claimed to have used over 300 pounds. Use per consumer increased at the rate of about 12 to 14 pounds per year, on the average, for the first 10 years of use.

Almost all the respondents (94%) said that they had been able to buy the kind of charcoal they wanted, and 84% preferred briquets. This answer on the part of the respondents must have been given by many without having made a direct comparison of lump and briquet charcoal. This conclusion is substantiated by the fact that, of 202 respondents who answered the question, 111, or 55%, claimed they had no previous knowledge of the lump type, and virtually all respondents stated that their present charcoal purchases were governed by market availability. It is thus very possible that the apparent high preference for charcoal in briquet form results primarily from the general unavailability of lump charcoal.

Throughout the state, most charcoal is sold in grocery and hardware stores. Other major retail outlets include lumber and fuel dealers, gas stations, and drug and sporting goods stores. The 10-pound bag was the size preferred by 58% of the users, although a significant number (34%) indicated that they would prefer a 20 or 25-pound bag.

Of the total respondents given a free bag of lump charcoal, 170 were willing to comment on its performance and offer preference opinions. Of these, almost 70% stated that they had no previous experience using lump charcoal. Fully 50% had used the entire bag of free charcoal. On the average, a 10-pound bag of lump charcoal was enough for at least five cookouts, or about two pounds per cookout. Of the respondents who offered an opinion, about 50% thought that equal weights of lump and briquet charcoal would cook about the same amount of food, 39% felt that briquets would go further than lump, and 11% felt that lump charcoal would go further than briquets. Many users apparently believe that equal volumes of lump and briquets weigh the same. This is wrong, however, because volumewise the lump weighs only about one-half that of briquets.

The most frequently mentioned desirable characteristics of lump charcoal were (1) ease of ignition, (2) rapid heating, and (3) better food flavor. These factors were associated mostly with the medium and mixed lump sizes. The most frequently mentioned undesirable characteristics were (1) too rapid burning, (2) too much sparking, and (3) too hard to ignite evenly.

Based solely on a comparison of the physical characteristics of lump and briquet charcoal, 26% of those who answered the question said that they preferred lump charcoal, 38% preferred briquets, and 37% rated the two kinds about equal.

When consumers were asked which kind of charcoal they would prefer with price also considered, a number of different answers were received. Based on the replies, it appears that if lump and briquet charcoal were

equally priced, 58% of the consumers would prefer briquets. If the price of lump charcoal were as much as two cents per pound more than briquets, only 17% of those who were willing to answer the question stated that they would still buy lump. However, if lump charcoal were to be priced two cents per pound below briquets, 68% of these respondents said they would prefer the lump. It would appear from these answers that price is probably a main consideration. Apparently with most consumers sampled in this survey, preference for either form of charcoal can be sharply modified by price differentials.

Conclusions

Even though based on a limited number of returns, the survey results suggest that lump charcoal might find a market in Iowa if it is stocked in retail stores and if its price is kept somewhat below that of briquets. The study tends to confirm the idea that consumers do not necessarily prefer briquet over lump charcoal, but that preference patterns presently established result primarily from the unavailability of lump charcoal.

With regard to the use of lump charcoal, the data show a need for consumer education. For example, since people are in the habit of waiting about 60 minutes or more for briquets to reach the right coaling stage, some do likewise with lump and find that it is nearly all consumed by that time. A lump fire is ready to use 15 or 20 minutes after ignition. Other users need to be informed that it requires twice as much lump volumewise to equal the same weight of briquets. Also, the technique of starting and obtaining an even bed of coals needs to be explained to many users, especially the new ones.

Even though the survey indicates that people are willing to purchase lump charcoal, the distributors are biased in favor of briquets because of past experience. Thus, producers of lump charcoal might find it difficult to find wholesalers or retailers willing to stock the lump charcoal.

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EVALUATION OF GLUE LINE QUALITY BY BLOCK SHEAR, PLYWOOD SHEAR AND CROSS-LAP TEST SPECIMENS[1]

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The gluing of wood has assumed increased importance in the conversion of lumber into marketable forest products. The emphasis on wood gluing has been brought about by the gradual depletion of the higher grade structural timber supply and the advent of synthetic resin adhesives. The increased use of glued products automatically creates a need for more research and information in the field of testing and evaluating glue line quality. Some of the primary purposes of testing glue line strength at a wood products plant are: (1) to determine whether a glue is strong enough for the intended purpose, (2) to learn whether or not it is of the same quality as previous shipments of similar glue, and (3) to disclose any possibility of poor practice in the use of glue. The number of methods used to evaluate glue quality is rather limited. The purpose of this study was to compare three of the test specimens used to make this evaluation—the plywood shear, block shear, and cross-lap specimens.

Test Specimens

Plywood Shear Test Specimen

The plywood shear test specimen (A.S.T.M. Standards D805-52) (1959) is normally cut from three-ply yellow birch plywood, each ply being 1/16 inch in thickness. Yellow birch (*Betula lutea* Michx.) is used because of its relatively high strength and density. The specimen is one inch wide, as measured across the grain of the face plies, and $3\frac{1}{4}$ inches long. A groove 1/8 inch wide is cut through the face and usually two-thirds the depth of the core at opposing ends and sides of the test specimen (Figure 1). The grooves are one inch apart, providing for a shear area of one square inch.

The plywood test specimens are loaded in tension shear by exerting a pulling force on each end of the specimen. Standard grips are used which clamp the specimen uniformly over one square inch surface area at each end of the specimen. Testing is usually done in a plywood testing machine, either the "shot" or fully automatic type. A uniform rate of

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loading of 600-1000 pounds per minute is usually employed. The total load and percentage of wood failure is obtained for each specimen.

The results obtained in plywood shear tests may vary considerably, even on duplicate specimens of plywood. Bensend and Preston (1954) showed that specific gravity, slope of grain of the face veneers and the elastic properties of the face and core veneer also caused a great variability in results.

Stress distribution for the plywood shear test specimen also varies considerably. Yavorsky (1955) found that, initially, the test specimen appeared straight in the grips, but application of the load caused bending to occur. The first failure is in cleavage (tearing stresses) near the notch. Northcott (1952) verifies that stress concentrations are set up notably at the base of the saw cuts. He reasoned that this causes the wood of many specimens to fail first in tension, followed by cleavage, even though the objective was to test the joint in shear.

Some advocates of the plywood shear test maintain that a large percentage of wood failure is sufficient to determine the acceptability of the plywood, contending that greater strength is not necessary. A test of this nature would tempt the manufacturer to use wood in the core that would result in the highest percentage of wood failure.

The plywood shear test specimen does lend itself well to glue line evaluation for several reasons:

1. The plywood type construction is one of the more typical applications of glued wood construction.
2. The specimen is small enough to be handled efficiently in large volume tests. It is easily prepared and quickly tested.
3. The specimen is thin enough to permit rapid penetration to and from the glue line, consequently it is sensitive to relatively short cycles of humidity and temperature.

Blomquist (1952) is of the opinion that none of the other test specimens seems to have as many advantages as the plywood shear specimens for durability investigations.

Block Shear Test Specimen

The standard block shear test specimen of hard maple (*Acer saccharum* Marsh) was also developed for the purpose of evaluating the adhesive strength of a glue. Specifications for preparation and testing of the specimen are given in A.S.T.M. D805-52 (1959). The standard specimen is 2 inches in width and 2 inches in height. Each lamination is $\frac{3}{4}$ inch in thickness and $1\frac{3}{4}$ inches in length with an overlap between the two laminations of $1\frac{1}{2}$ inches. The resulting shear area is then 3 square inches. The grain direction of the individual laminations is parallel to the direction of loading (Figure 1).

The maple block shear specimens are loaded in compression in a self-aligning tool in an attempt to provide uniform lateral distribution of the load. Testing is usually accomplished in a universal testing machine adjusted to provide a continuous head motion of 0.015 inch per minute. Maximum shear stress in pounds per square inch, based on a glue line area of 3 square inches, and percentage of wood failure are the only values obtained.

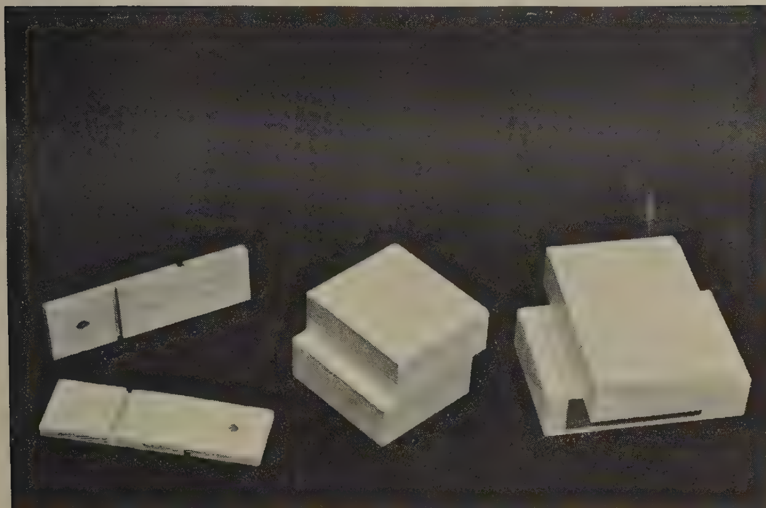

Figure 1. Glue joint test specimens: Plywood shear on the left, block shear in the center, and cross-lap on the right.

The causes of variability in block shear test results are similar to those for plywood shear. The existence of high stress concentrations near the re-entrant corners and the nonuniform shear stresses imposed over the test specimen because of the geometry of the specimen and the method of loading have been noted by Yavorsky (1955).

Since it is believed that neither pure nor uniform shear stress exists in the plane of the glue joint, Yavorsky and Cunningham (1955, p. 83) made the following statements about factors which they think should be considered when evaluating the results of a maple glue block test:

> "The shear stress computed by dividing the loads by the area of the glue joint is an average shear stress. The occurrence of strain cracks at very low loads near the re-entrant corners of the block shear indicates high stresses in these areas. Failure will be initiated in these regions of maximum stress, and a stress concentration factor should be determined in order to establish the magnitude of stress when rupture occurs." . . .
>
> "The presence of stress components normal to the plane of the glue joint and normal to the longitudinal grain direction in the wood imposes stresses which must be resisted by the cohesive strength of the glue and the tensile strength of the wood-glue interface and by the wood itself. Since the tensile strength of the interface and the wood perpendicular to the grain are considerably less than the respective shear strengths, failure may occur due to tensile stresses instead of shear stress."

Elmendorf (1952) is of the opinion that most wood members, which are placed crosswise or crossbanded when glued, are subjected to cleavage stresses when the wood shrinks. He also contends that the high shear strength in a glue line is generally an indication of high cleavage strength. Insofar as this is the case, he believes that the block shear specimen is a reliable test. In any case, he states, the block shear test is a simple test, and the layman as well as the technician understands it.

The block shear test specimen has been used extensively in studies on the effect of assembly time, pressure, amount of glue spread and other factors that affect the strength of the joint. It is also a good test of the strength of the joint in samples of commercially glued wood, since test specimens can be cut from glued blocks of almost any shape as long as they are of sufficient size and have laminations of sufficient thickness.

The Cross-lap Test Specimen

The cross-lap specimen is a relatively new means of evaluating adhesives in wood to wood bonding. Most of the development work has been done by A. A. Marra (1954) and Foreste (1950). Standard dimensions have not as yet been specified. A.S.T.M. D1344-55T (1955) is a tentative method, or procedure, for testing cross-lap specimens but deals primarily with the bonding of materials other than wood.

The cross-lap specimens used in this study were constructed of maple blocks $\frac{3}{4}$ inch thick, 2 inches wide and 3 inches long (Figure 1). This gave a cross-lap area of 4 square inches with a $\frac{1}{2}$ inch bearing surface on both sides.

Marra (1955) discusses the development and the initial work done with the cross-lap specimen. He was interested in developing a more useful type of test specimen based on tension because adhesive bonds are believed to be stressed in tension rather than in shear. He also thought it desirable to have a specimen that concentrates the loading stresses in the bond, thus reflecting the true strength of the glue bond with more uniformity and certainty. The block shear specimen tests the glue line in its strongest dimension, while it is often desirable to test materials in their weakest dimension. The cross-lap specimen then appears to be more indicative of the true strength of laminated members.

In testing the cross-lap specimen, two types of grips have been used: the self-aligning and the rigid (Marra 1955). The self-aligning grip responds to forces both parallel and perpendicular to the load axis. The rigid grip, when used in a universal testing machine, has bearing edges that deliver the load at points of highest elevation. The load is applied as a compressive force but reaches the glue line as tensile force components. A modified rigid type grip was used in this study.

Investigation

In this investigation among the many factors affecting glue line quality, type of adhesive, assembly time, and high and low humidity exposure of the cured bonds were selected for study. The objective was to evaluate the response of three different types of test specimens to variation of these factors.

Material

The lumber used for the cross-lap and block shear test specimens was 4/4 kiln dried hard maple. The lumber was inspected for straightness of grain and defects such as knots, mineral streaks, birds-eye figure and discoloration indicative of decay. Specific gravity based upon oven-dry volume was determined for each board used by the water-displacement method. The material was then grouped by specific gravity and conditioned to approximately 8% M.C. The veneer used for the three-ply plywood shear specimens was 1/16 inch rotary cut yellow birch. The material was examined for straightness of grain and the presence of defects. Relative weight figures were used to help control specific gravity.

Gluing Procedure

Three room-temperature-setting, synthetic-resin adhesives, urea-formaldehyde, resorcinol-formaldehyde, and polyvinyl were used in this study. These particular adhesives were chosen because they are quite representative of the adhesives used in industry.

In this study, three different assembly times were used for each glue. One combination of open and closed assembly time was the optimum condition as stated by the manufacturer. The other two assembly times were set at what were considered to be a lower limit and an upper limit. The adhesives and the assembly times used were as follows:

Glue	Assembly Time (Minutes)	
	Open	Closed
Urea formaldehyde	0	10
	$3\frac{1}{2}$	10
	7	10
Resorcinol formaldehyde	0	10
	5	10
	10	10
Polyvinyl resin	0	10
	5	10
	10	10

Each glue was mixed in accordance with the manufacturers recommendations.

The cross-lap blocks, the block shear billets, and the veneer for the plywood specimens were assembled, after being spread with glue (approximately 35 pounds per M square feet), and allowed to stand the designated open assembly time. Pressure was applied after the closed assembly period had elapsed. Pressure was applied to the cross-lap specimens by means of a spring loaded rig, the initial load being applied by a small laboratory hydraulic press (Figure 2). After application of pressure, the retaining screws were tightened and the jig removed from the press. A spherical bearing block incorporated with the spring gave uniform load application. The blocks were assigned a position in the rig

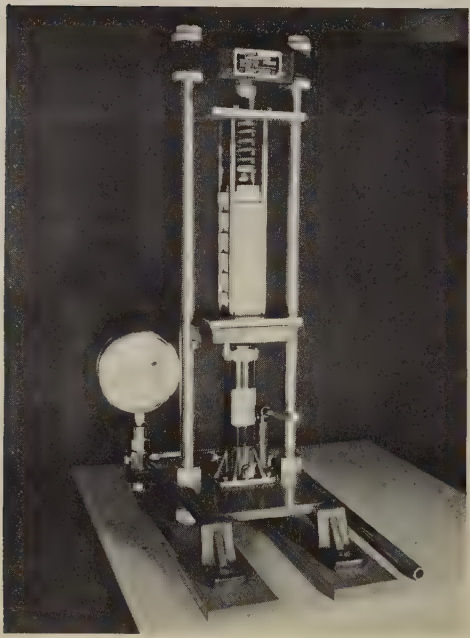

Figure 2. The cross-lap specimens assembled in the gluing jig showing application of pressure in the laboratory press.

so that possible variation in position within the rig could be controlled statistically. The glue squeeze-out was removed immediately after application of pressure to insure a smooth bearing surface for testing. Pressure was applied to the block shear billets using three bar clamps and measured by means of a torque wrench. The yellow birch plywood from which the plywood shear test specimens were cut was assembled in the form of 5 x 10 inch panels with the grain of the face plies at right angles to the long dimensions. Pressure was applied in a jack screw press using a torque wrench. A pressure of 150 psi was applied to all the assemblies, and they remained under pressure for 18 hours. After the pressure period, the glued stock was conditioned in a humidity chamber for four days at an E.M.C. of 8%. The plywood shear and the block shear specimens were then cut from the glued stock in accordance with A.S.T.M. specifications D805-52 (1959). Six block shear specimens were cut from each pair of billets, and six plywood shear test specimens were cut from each 5 x 10 inch panel. All specimens were reconditioned in the humidity chamber to a moisture content of 8 ± 1%.

Treatments or Exposure Conditions

Three different humidity exposure conditions were used in this study. They were:

1. T1 or the control portion of the experiment. The control specimens, one-third of the total or 216 specimens, were tested after being conditioned at 8% E.M.C.

2. T2. This test was made after the specimens were cycled in the humidity chamber set on the following cycling program:

   a. Three weeks at 8% E.M.C. (100°F and 47% R.H.) This was the initial conditioning period.

   b. One week at 20% E.M.C. (110°F and 92% R.H.)

   c. One week at 8% E.M.C. (100° F and 48% R.H.)

   d. One week at 20% E.M.C. (110°F and 92% R.H.)

   T2, or the second test, was performed in a wet condition or at the end of step d.

3. T3. The last test followed the same cycling schedule as T2, except that after the tests for T2 had been completed the conditioning chamber was set back to 8% E.M.C. for a week before the T3 tests were performed.

Testing

The cross-lap specimens were tested using self-aligning testing grips with a spherical bearing block in a Universal 60,000 lb. hydraulic testing machine (Figure 3). The testing specifications as given in A.S.T.M. D1344-54 were followed, except that total failing load in pounds was recorded. In addition, data were recorded on percentage of wood failure, and moisture content samples were randomly selected at the time of testing.

The block shear specimens were tested in accordance with A.S.T.M. specifications D805-52. A conventional shear tool was used in the same hydraulic testing machine used for loading the block shear specimens. Data were collected on total load, later converted into pounds per square inch, and on percentage of wood failure in the bond area. Moisture content samples were also taken at the time of testing.

The plywood specimens were tested in a standard shot plywood shear testing machine in accordance with A.S.T.M. D805-52. The testing machine was set to deliver a continuous load of 740 pounds per minute until failure. The load at failure and the percentage of wood failure were recorded for each specimen. The use of a bond area of one square inch gave a direct reading of pounds per square inch of shear area. A representative number of moisture content samples was also taken at time of testing.

Figure 3. The test grips for the cross-lap specimens in operation in the hydraulic testing machine.

RESULTS AND DISCUSSION

Plywood Shear Tests

Glues: Plywood shear specimens bonded with polyvinyl, urea and resorcinol resins produced joints of quite uniform strength. This uniformity is verified by the fact that in the analysis of variance for plywood shear (Table 1) the difference in glues failed to reach the 5% level of significance.

Considering all glues together, the two factor interaction of glues x assembly time and the three factor interaction of glues x assembly times x treatments were found to be nonsignificant. However, in the two factor interaction of treatments x glues, a significant difference at the 1% level was found. This indicates that cycling affects the glue bond strength more with some glues than with others.

Assembly times: The assembly times used for the glues did not have a significant effect on the test results. This indicates that satisfactory bonds of similar strength were obtained for each variation of assembly time used.

Treatments: The effect of the three treatments or cycling conditions on the failing strength of the plywood shear specimens was found to be significant at the 1% level. The two factor interaction of treatments x assembly times and the three factor interaction of glues x assembly times x treatments were found to be nonsignificant.

Table 1. Analysis of variance for the strength of plywood shear test specimens by glues, assembly time, and test specimen treatment.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Replications R	1	332,918	332,918	4.11
Glues G	2	1,485,285	742,643	9.17
Error (a) R x G	2	161,955	80,978	
Blocks within G and R	6	98,860	16,477	
Assembly times A	2	133,664	66,832	
G x A	4	218,403	54,601	
Error (b) RxA + RxGxA	6	317,102	52,850	
A x blocks within G and R	12	72,215	6,018	
Subblocks within R, G, and A	36	61,592	1,711	
Treatments T	2	101,204	50,602	8.28*
G x T	4	378,001	94,500	15.46*
A x T	4	15,226	3,807	
G x A x T	8	36,694	4,587	
Error (c)	18	110,038	6,113	
T x subplots treated alike	36	136,237	3,784	
T x subblocks within R, G, and A	72	181,583	2,522	
Total	215	3,840,977		

* Significant at the 1% level.

Additional Sources of Variation: In the randomized block design of this experiment the object was to make the specimens within a block or group as similar as possible. In this study, several sources of variation were controlled to help reduce the experimental error. In Table 1, blocks within glues and replications (G and R) refer to the grouping of panels to help control variation due mainly to the difference in specific gravity. It was found that there was no significant difference between these blocks or groups within glues and replications. Likewise, the difference between subblocks within replications, glues and assembly times was not significant. A subblock refers to the grouping together of one series of the three treatments within the original panel of six specimens. Subplots treated alike is the grouping together of specimens within a panel that have a similar assembly time-cycling test designation.

Block Shear Tests

Glues: With the block shear test specimens a significant glue effect was observed (Table 2). Polyvinyl resin and resorcinol formaldehyde produced bonds of similar strength, but urea formaldehyde was considerably lower, especially in treatments two and three. Table 2 shows

Table 2. Analysis of variance for the strength of block shear test specimens by glues, assembly times, and test specimen treatment.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Replications R	1	48,002	48,002	8.44
Glues G	2	19,851,865	9,925,933	1,745.37*
Error (a) RG	2	11,374	5,687	
Blocks within G and R	6	354,470	59,078	
Assembly times A	2	67,676	33,838	
G x A	4	246,502	61,626	
Error (b)	6	1,078,059	179,677	
A x blocks within G and R	12	1,166,984	97,249	
Subblocks within R, G, and A	36	3,298,412	91,623	
Treatments T	2	92,196,848	46,098,424	454.8*
G x T	4	29,888,602	7,472,150	73.7*
A x T	4	580,803	145,201	
G x A x T	8	1,417,594	177,199	1.75
Error (c)	18	1,824,385	101,355	
T x subplots treated alike	36	5,292,478	147,013	
T x subblocks within R, G, and A	72	5,637,702	78,301	
Total	215	162,961,756		

* Significant at the 1% level.

nonsignificant values for the two factor interaction of glues x assembly times and the three factor interaction of glues x assembly times x treatments. As in the plywood shear tests, treatments and the two factor interaction of treatments x glues were both significant at the 1% level.

Assembly times: Similar to the plywood shear portion of the study, the assembly times used for the glues did not have a significant effect on the test results.

Treatments: The effect of the three variations of cycling conditions or treatments on the failing strength of the block shear test specimens was found to be significant at the 1% level. As indicated previously, the two factor interaction of treatments x glues was significant at the 1% level, but other interactions involving treatments were not found to be significant.

Additional sources of variation: Blocks within glues and replications, subblocks within replications, glues and assemblies and subplots treated alike were all found to be nonsignificant, which indicates that they can be regarded as being quite similar in nature. The definition of these sources of variation is similar to the corresponding partitioned variation in the plywood shear study.

Table 3. Analysis of variance for the strength of cross-lap test specimens by glues, assembly times, and test specimen treatment.

Source of variation		Degrees of freedom	Sum of squares	Mean square	F
Replications	R	1	250,785	250,785	
Glues	G	2	1,815,306	907,653	
Error (a)	RG	2	1,433,268	716,634	
Blocks within G and R		18	1,685,306	93,628	
Assembly time	A	2	351,119	175,560	
Treatments	T	2	6,494,189	3,247,094	20.33*
A x T		4	109,929	27,482	
G x A		4	194,212	48,533	
G x T		4	24,494,931	6,123,733	38.33*
G x A x T		8	385,628	48,204	
Error (b)		24	3,834,018	159,751	
Subplot treatments x blocks /glues and replications		144	10,827,630	75,192	
Total		215	51,876,321		

* Significant at the 1% level.

Cross-lap Tests

Glues: A nonsignificant glue effect was observed with the cross-lap test specimen (Table 3). As with the other test specimens, there was a significant two factor interaction of glues x treatments. The other interactions involving glues as a variable failed to be significant at the 5% level.

Assembly times: Similar to plywood shear and block shear specimens, the cross-lap did not show a significant difference in failing strength resulting from different assembly times used.

Treatments: The different cycling treatments used on the cross-lap specimen did produce results that were significantly different at the 1% level. The interaction of glues x treatments was again significant at the 1% level, but other interactions involving treatments were nonsignificant.

Additional sources of variation: In the cross-lap analysis, blocks within glues and replications (G and R) refer to nine specimens, each receiving a different combination of assembly time and treatment. Within each replication and glue, six gluing rigs containing six specimens each were used. These rigs were divided into blocks of similar specific gravity, and the analysis showed that blocks within glues and replications were not significantly different at the 5% level.

Test Specimen Comparison by Glues

Polyvinyl: A comparison of failing strength and wood failure of block shear, plywood shear and cross-lap test specimens by treatments using

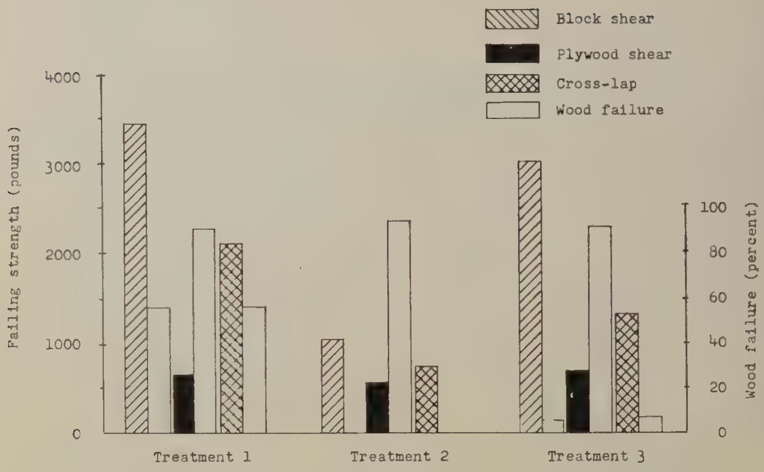

Figure 4. A comparison of failing strength and wood failure of the Block Shear, Plywood Shear, and Cross-Lap test specimens by treatments using polyvinyl resin glue.

polyvinyl resin is shown in Figure 4. The failing strength for the block shear tests is given in pounds per square inch, while that for the cross-lap tests is given in pounds of total load applied. It appears that the block shear and cross-lap test specimens are more sensitive to the effects of moisture on the strength of the glue bond than the plywood shear test. It is also shown that following moisture exposure the strength of polyvinyl resin was still sufficient to develop the veneer strength in the plywood shear test specimen but not strong enough to develop the shear strength of the block shear specimen or the tension perpendicular to the grain strength in the case of the cross-lap specimen. The veneer used for the plywood shear specimens appears to have insufficient strength to give an adequate test of the glue itself.

Resorcinol Formaldehyde: Figure 5 gives a comparison of the three test specimens when bonded with resorcinol formaldehyde.

It appears again that the block shear and cross-lap specimens are more effective in testing glue line quality. This is verified by the fact that in both the block shear and cross-lap specimens the percentage of wood failure is considerably lower than for plywood shear, indicating that the glue line and not the wood is being tested.

It is also evident for resorcinol that the moisture content of the specimen does not affect specimen adjustment in the grips in testing the block shear specimen to the extent it does the plywood shear and cross-lap specimens.

An additional feature of the block shear is brought out by the fact that it regained failing strength under treatment three, whereas the other two

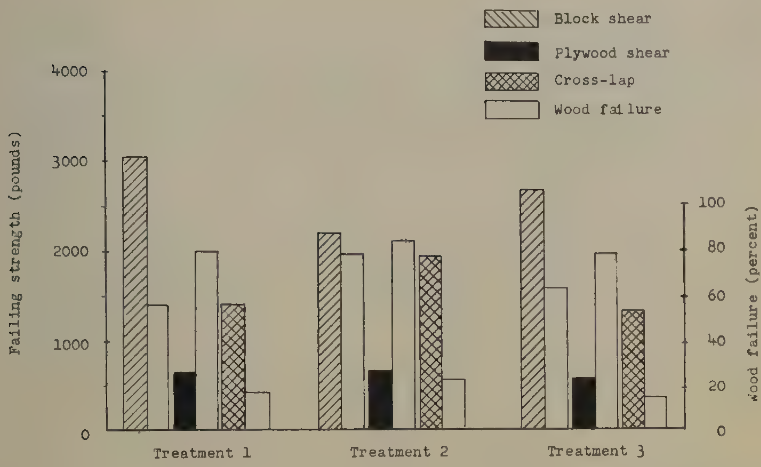

Figure 5. A comparison of failing strength and wood failure of the Block Shear, Plywood Shear, and Cross-Lap test specimens by treatments using resorcinol formaldehyde glue.

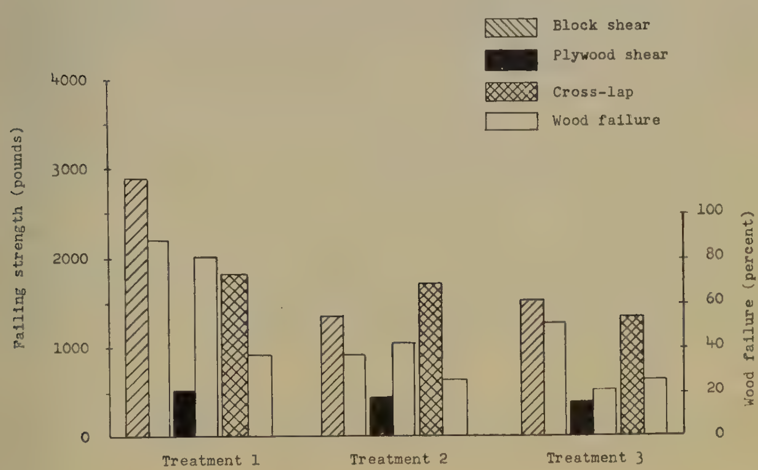

Figure 6. A comparison of failing strength and wood failure of the Block Shear, Plywood Shear, and Cross-Lap test specimens by treatments using urea formaldehyde glue.

specimens decreased in failing strength. This may be due to the nature of the construction of the block shear resulting in less severe glue line stresses during cycling.

Urea Formaldehyde: A comparison of the different test specimens when bonded with urea formaldehyde is given in Figure 6. Strength values for the block shear specimens tested in treatment 2 were considerably lower in proportion to the control values than were the plywood shear or cross-lap specimens. The average failing strength was the lowest for all the glue-test specimen combinations when using urea formaldehyde, except for the cross-lap specimens bonded with resorcinol and polyvinyl which were slightly lower than the average urea cross-lap value. It seems evident that the reduction in failing strength was due to the glue itself and not to the gluing conditions or moisture content of the wood. This also indicates a possibility that glues may vary in their ability to withstand shear and tension perpendicular to the grain loads. Urea might be comparatively stronger in tension perpendicular to the grain than in shear.

CONCLUSIONS

Block Shear

The standard glue block shear specimen, constructed of hard maple blocks $1\frac{3}{4}$ inches x 2 inches with a glue line area of 3 square inches, appeared to provide the best evaluation of glue line quality. The block shear test results indicated the following:

1. The block shear specimens were more sensitive to higher relative humidities as indicated by decreasing failing-strength of the specimens after being exposed to 110°F and 92% relative humidity (20% E.M.C.). The block shear specimens, however, have a greater ability to recover strength when conditioned from a high humidity (20% E.M.C.) to a low humidity (8% E.M.C.). This would indicate that internal stresses resulting from expansion and contraction of the wood are not as great in the block shear as in the cross-lap and plywood shear test specimens.

2. The block shear specimen gave the highest strength values. This may be due to the fact that wood is stronger in shear parallel to the grain than in tension perpendicular to the grain, or it may be due to a difference between the two strength properties of the glues. If a glue line has the same strength in tension as in shear, the block shear would provide a more severe test.

3. The block shear specimen was the only test specimen to detect a significant difference in failing strength among the three different glues. The effect of glues and treatments on the type of wood failure is shown in Figure 7.

4. There is a more nearly equal loading stress applied to the glue line of the block shear specimen resulting in less effect of moisture on specimen adjustment in the grips.

Figure 7. Types of wood failures in the block shear test as related to adhesives and treatment of bonded joints. Upper horizontal line bonded with polyvinyl, middle with resorcinol and lower with urea. The vertical column, A, consists of the controls; B, the specimens tested at 20% moisture content after cycling; and C, tested at 8% moisture content after cycling.

Plywood Shear

Using the standard plywood shear test specimen cut from three-ply yellow birch plywood with notches cut in the specimen providing 1 square inch of glue line shear area, the following observations were made:

1. The plywood shear specimens produced the highest average amount of wood failure. The veneer used for the plywood test specimens appears to be of insufficient strength to provide an adequate test of the glue line. Many failures occurred in the core ply as a result of rolling shear (see Figure 8 for types of wood failure).

2. Plywood shear specimens when tested at a high moisture content have a tendency to adjust to the stress being applied resulting in higher failing strength values.

Cross-lap

The cross-lap specimens were constructed of $\frac{3}{4}$ inch thick lumber cut into blocks 2 inches wide and 3 inches long giving a 4 square inch glue line. Tension perpendicular to the grain tests gave the following results:

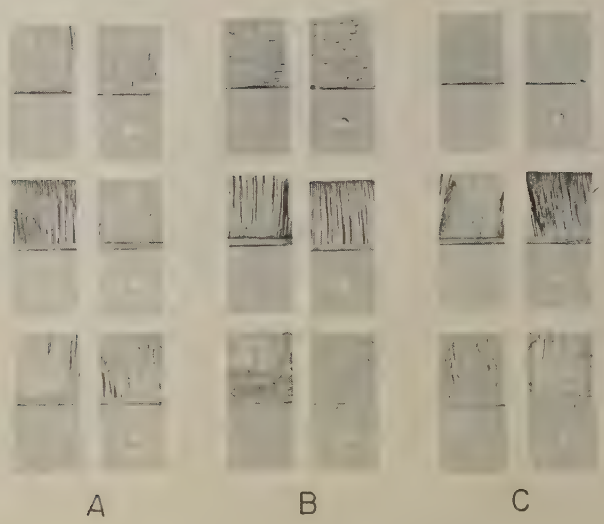

Figure 8. Types of failures in the plywood shear test as related to adhesives and treatment of bonded joints. Upper horizontal line bonded with polyvinyl, middle with resorcinol, and lower with urea. The vertical column, A, consists of the controls; B, the specimens tested at 20% moisture content after cycling; and C, tested at 8% moisture content after cycling.

1. Considerable variation in maximum strength and wood failure occurred in cross-lap specimens given similar treatment.

2. When testing glues of high moisture resistance such as resorcinol, cross-lap specimens tested at higher moisture contents gave higher failing strength values and perhaps false strength observations because of the increased plasticity of the wood resulting in more bending and adjustment to the load being applied.

3. The low percentage of wood failure for the cross-lap test specimens suggests that the loading stresses were perhaps concentrated more at the glue line than in the wood, resulting in a better test of the glue. This may also indicate that the adhesives used have a low tensile strength in comparison with shear strength. Figure 9 shows representative types of wood failure for the cross-lap specimens.

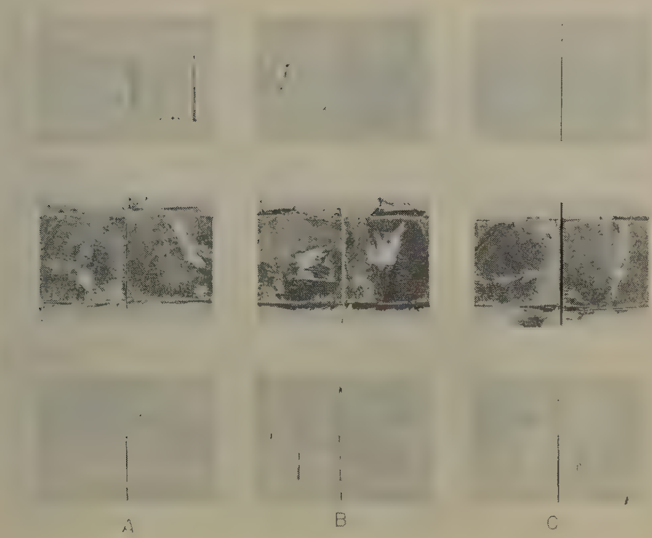

Figure 9. Types of wood failures in the cross-lap test as related to adhesives and treatment of bonded joints. Upper horizontal line bonded with polyvinyl, middle with resorcinol, and lower with urea. The vertical column, A, consists of the controls; B, the specimens tested at 20% moisture content after cycling; and C, tested at 8% moisture content after cycling.

Glues

The three resin adhesives used for this study, urea formaldehyde, resorcinol formaldehyde and polyvinyl, responded differently to the three cycling treatments.

1. The average failing strength by treatments was the lowest for all glue-test specimen combinations when using urea formaldehyde, except the cross-lap control and treatment 3 specimens glued with resorcinol, and the block shear and cross-lap specimens glued with polyvinyl and tested after treatment 2.

2. Polyvinyl resin strength was reduced the most by the high humidity treatment (T2) but regained the greatest amount of strength when conditioned from a high humidity to a low humidity.

3. Resorcinol formaldehyde exhibited the greatest resistance to high relative humidities in all three test specimens, as indicated by the high retention of failing strength values under treatment 2.

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PLANT COVER AND FORAGE USE OF ALPINE SHEEP RANGES IN THE CENTRAL ROCKY MOUNTAINS

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Above the limits of tree growth in the central Rocky Mountains are extensive areas of herbaceous and low-growing, woody vegetation intermingled with rocky, barren wastes. These areas, known as Petran or alpine tundra (Weaver et al., 1938), furnish forage for large bands of domestic sheep. These alpine areas are the headwaters of most major streams of the region, and they are superb recreation areas.

In the summers of 1955 and 1956, an extensive survey of alpine sheep ranges was made in Colorado, Wyoming, and New Mexico. The gross characteristics of the alpine vegetation and some of the aspects associated with its grazing use are reported here.

MAJOR PHYSICAL FEATURES

There are nearly 5 million acres of alpine range in the central Rocky Mountains. It occurs as a series of discontinuous segments confined to the tops of the higher mountain masses (Figure 1). In some respects it appears as a rather monotonous panorama in a generally harsh, physical environment. However, differences in slope, soil, exposure, and available moisture are great, as are variations in plant cover and grazing values.

In places the demarcation of forest and grassland is abrupt, while in others it is less distinct. Lower elevation limits of the alpine range from approximately 12,000 feet in New Mexico to about 10,000 feet in northern Wyoming. These limits may vary greatly with local exposure.

Geologically, the alpine tundra is complex; igneous, sedimentary, and metamorphic rocks are represented. Ancient core rocks that make up the higher peaks include granites, grandiosites, gneisses, schists, slates, and quartzites (Atwood, 1940). There is much faulting, folding, intrusion of igneous masses, and extrusive lavas which complicate the physiognomy.

Glacial action has been responsible for many topographic features, including the "bowl-like" cirques and "U-shaped" valleys. With stream channeling, glacial activity, or surficial shifts, the relief in many places has become one of steep slopes and sheer rock cliffs, but the topography is gently undulating where peneplain remnants persist.

Alpine soils differ as a result of drainage, exposure, and variations in parent rocks. Three groups were described by Retzer (1956) as alpine turf, alpine meadow, and alpine bog soils.

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Figure 1. The alpine ranges of the central Rocky Mountains include broad expanses of treeless grassland, rocky wastes, and the transition zone above the spruce-fir forests.

On well-drained slopes and ridges, surface soils of the alpine turf are black to dark brown, and subsoils are variations of brown. The A horizon averages about 7 inches thick, and rarely is the soil profile more than 20 inches thick. Horizon development is more distinct than in alpine meadow or bog soils.

Alpine meadow soils are black or very dark brown mineral soils, which have developed under imperfect to poor drainage. They have highly organic surface soils, which are not peaty as in bog soils, but they often exhibit subsurface mottling. Variations are due to stratification of the parent materials and wetness of the area; some layers are fine-textured and others are coarse and stony. More profile variation exists in these soils than in the turf soils.

The texture of turf and meadow soils is commonly a loamy sand or gravel. There is usually only weak, granular structural development. In the subsoil, rock fragments of all sizes are abundant. Most soils are acidic, pH ranging between 5.0 and 6.0. Where soils have developed from calcareous parent material, the reaction is basic.

Bog soils are found where water is ponded for all or part of the year, or where the soil is continuously wet. They are black or brown peaty soils, often with very little mineral soil present. Peat overlaying a substratum of rocks and gravel may be 2 feet or more in thickness.

Climatic data from the alpine type of the central Rocky Mountains are limited mainly to the summer period. During the winter, early spring,

and late fall, human habitation is sporadic and of short duration because of the severe climate and general inaccessibility of the region. A few stations have been maintained intermittently and furnish an indication of alpine weather conditions. From these, it is evident that precipitation, most of which falls as snow, varies widely by location and years. Weather records for Colorado (Cox, 1933; Dodds, 1917; Whitfield, 1933), indicate that above 11,000 feet the average annual precipitation is probably between 30 and 50 inches. During the 2 months, July and August, when the vegetation is most actively growing, rainfall extremes of 2.43 inches to 10.60 inches have been recorded; precipitation in these 2 months was usually between 5-8 inches. Mean annual temperatures were approximately 30°F, with summer maximums between 64°F and 76°F, and winter minimums between -11°F and -23°F. Winter lows are frequently higher than at stations at lower elevations; nevertheless, the climatic regime of these high elevations is severe for both plants and animals.

THE PLANT COVER

The general alpine aspect is frequently described as grassland, but the flora is more accurately a mixture of many grasses, grasslike plants, forbs, and woody shrubs. Numerous local site differences due to peculiarities of soil, topography, and climate are responsible for the apparent heterogeneity of the vegetation complex.

The transition between alpine grassland, and the subalpine forests consists of individuals of subalpine fir (Abies lasiocarpa (Hook.) Nutt.),[1] Engelmann spruce (Picea engelmannii Parry), limber pine (Pinus flexilis James), and bristlecone pine (P. aristata Engelm.). These are stunted and flat-topped because branches, which extend above the snow cover, are sheared off by wind-driven particles of sand and ice. At the irregular terminus of the trees, the vegetation aspect becomes treeless grassland or barren rock. Herbaceous species from the alpine areas above, and the forests below, intermingle in this grassland-forest ecotone.

All gradations from dry to extremely wet sites are encountered in the treeless grasslands. Where the soil remains moist but not saturated throughout the growing season, the plant community is lush, and several taller grasses and sedges (Carex spp.) dominate the plant cover. Meadow communities are common in the basins or slight depressions, below cirques, and on slopes and benches that are more sheltered or where drainage is restricted.

On certain sites, relatively dense stands of willows (Salix spp.) indicate the presence of a moist substratum (Cox, 1933). Wide differences in growth form are found between the several willow species. Some are upright, typical shrubs, but others are low and mat-like, seldom over an inch or two high. Other low-growing, locally abundant shrubs include Mt. Washington dryad (Dryas octopetala L.) and whortleberry (Vaccinium spp.).

Where the soil is well drained and exposure is more extreme, the vegetation is typically low and turf-like. It is found as a tough sod, which forms a layer of humus one to several inches thick. When the sod is

[1] Nomenclature follows Harrington, H.D. "Manual of Plants of Colorado."

Figure 2. Erosion becomes severe when the tough sod cover on exposed alpine sites is broken.

intact it provides protection from the strong winds and high intensity rains; however, once it is broken soil erosion becomes severe (Figure 2).

These areas are commonly free of snow most of the winter and do not receive the protection of the snow cover. They are, therefore, exposed to lower temperatures and the desiccating, abrading effects of winter winds, which are frequent and strong.

Vegetation growth on exposed sites is dependent largely upon moisture received during the growing season. It undergoes intermittent periods of drought stress, especially during the latter part of the summer. In 1956, for example, as the surface humus layers dried out, fissures up to an inch wide were observed in alpine turf.

Commonly the plants are mat- or cushion-shaped on sites that have extreme exposure, poor soil, and less favorable soil-water conditions (Figure 3). Upright plant forms may become established on these wind-swept areas within the periphery of the cushion plants. Griggs (1956) has prepared a tentative competitive ladder of plant succession on such areas. Species frequently encountered as cushion plants include moss silene (Silene acaulis L.). Siberian sandwort (Arenaria sajanensis Willd.), Rocky Mountain nailwort, (Paronychia pulvinata Gray) and dwarf clover (Trifolium nanum Torr.).

In general, successional relations of the alpine tundra are not well understood (Weaver and Clements, 1938; Hanson, 1951). In his studies of the related arctic flora, Polunin (1955) states that plant communities are very complex, and numerous biotypes exist because of hybridization,

Figure 3. Cushion forms of plant life are often typical of severely windswept sites.

wide climatic tolerances, mutation induced by the rigorous climate, a low degree of biotic competition, and the many microhabitats. Hanson (1953) points out that various soil properties, such as texture, mineral and organic composition, reaction moisture relationships, freezing and thawing processes, in addition to the amount and duration of snow cover, exposure, biotic influences from grazing, rodents, plant competition, and various man-caused influences, are all important factors in determining the vegetation.

Methods of Vegetation Study

Thirty-three alpine areas were examined. They represented a variety of conditions of topography, vegetation, and grazing use. Some areas were studied more intensively than others, depending upon the diversity of conditions each exemplified. The intent was to describe and evaluate the major vegetation types. Sites that seemed to typify major portions of each area were selected for detailed study.

Quantitative measurements of the plant cover were obtained by placing a loop, $\frac{3}{4}$ inch in diameter, at the tip of the right shoe along 100-pace transects. In most cases two randomly located pace transects, which originated from a common hub, were measured to characterize the vegetation of each site. At each pace the plant base or other kind of ground cover within the loop was recorded. Transect data that were recorded included plant cover, litter and moss, bare ground, and rocks. Because

of the uncertainty of identification when floral parts were not available, many of the forbs, bluegrasses (Poa spp.), most sedges and willows were identified only to their respective genera.

In addition to the ground cover measurements, herbage production was determined by the weight-estimate method (Pechanec et al., 1937b) within a 9.6 sq. ft. circular frame. Five plots were placed along each pace transect. Where grazing by domestic sheep or big game animals had occurred when the allotment was visited, estimates of species utilization were made within the circular frame according to the ocular-estimate-by-plot method (Pechanec et al., 1937a).

Alpine Turf Sites

Thirty-two alpine turf sites were studied on 16 areas within 8 national forests. Turf sites were found on all aspects and on slopes ranging from 0 to 50%; slopes steeper than that, although present, were not considered to be representative of a large segment of any areas visited and therefore were not sampled. Almost $\frac{3}{4}$ of the turf sites examined were on south or west exposures.

On each site there was some bare ground. The average number of measurements on bare ground with the $\frac{3}{4}$ inch loop was 17 with a range of 3 to 54 on the 32 sites. Twenty-eight sites had an average of 8.2 measurements on rocks. Litter and moss averaged 17.7 measurements on each site with a range of 2 to 42.

A total of 69 species and genera were encountered on the turf sites. Indices from the transect data of the plants that ranked highest according to the product of their frequency and abundance are given in Table 1.

Table 1. Characteristic plants of alpine turf sites ranked according to the product of their frequency and abundance.

Plant	Index of frequency X abundance	Frequency of Occurrence (%)	Average abundance per site[1] (%)
Kobresia and Carex elynoides	1035	75	13.8
Other sedges	737	91	8.1
Dwarf clover	508	62	8.2
Upright clover	480	75	6.4
Golden avens	413	78	5.3
Bluegrass	308	81	3.8
Alpine oreoxis	299	44	6.8
Siberian sandwort	262	69	3.8
Moss silene	192	31	6.2
Alpine sagebrush	191	66	2.9
Sheep fescue	119	34	3.5

[1] Number of encounters per 100 loop observations.

On the turf sites plant cover varied from 24 to 89%, as measured by the loop method. Plant cover on the 32 sites averaged 58%; 12 of the sites (37%) had a plant cover index above 60% and 5 (16%) were below 40%. Plant cover was from 40-60% on 15 (47%) of the sites. Representative areas of each plant cover class are shown in Figure 4.

On turf sites relatively few species provided a dense vegetative cover. The 12 plants whose frequency-abundance index was more than 100 accounted for 81% of the plant cover. Moreover, these plants provided 80% or more of the plant cover on those sites which had the lowest as well as the highest plant cover.

Fifty-seven plants that were recorded on the turf sites had an index of less than 100. Among these, 6 were stunted trees or low shrubs, none of which had an index higher than 12, 44 forbs, and 7 grass or grasslike plants. The two most common shrubs were Mt. Washington dryad and 2 species of dwarf willow (Salix anglorum antiplasta Schn. and S. nivalis Hook.). More than 46% of the plants had an index of less than 10.

Most alpine turf sites were characterized by kobresia (Kobresia bellardi (All.) Degl.) or Carex elynoides Holm. and other sedges, several bluegrasses, clovers (Trifolium spp.) and golden avens (Geum turbinatum Rydb.). In places the plant cover was an almost unbroken sod. Usually such areas were localized although several were very extensive.

On the well vegetated sites the plants named made up 78% of the composition, of which grass and grasslike plants contributed 49%. Among other grasses, spike trisetum (Trisetum spicatum (L.) Richt.) was often present in minor amounts.

Carex drummondiana Dewey was also found as a sod-former of the alpine turf sites. Local areas in Colorado and rather extensive areas in northern Wyoming were sampled where this species was dominant.

Except for the clovers and golden avens, forbs ordinarily do not contribute appreciably to the plant composition where the sod cover is almost continuous. Upright clovers, which include Parry clover (Trifolium parryi Gray), whiproot clover (T. dasyphyllum T. and G.), or Brandegee clover (T. brandegei Watson), were recorded on most turf sites. They constituted on the average 17% of the plant composition. Dwarf clover, which is common on windswept alpine sites, was also present in small amounts on these better sites. It usually did not occur as a distinct, regularly shaped, cushion plant as on the more exposed sites but was often found within partial openings in the sod cover.

Golden avens was another persistent species in the plant cover of turf sites. It was present on 78% of the sites and averaged 10% of the plant composition.

Other forbs were often recorded and certain species were occasionally more abundant than the more persistent ones described above. For example, alpine oreoxis (Oreoxis alpina (A. Gray) Coult. and Rose) made up 21% of the plant composition on one site. Total plant cover on this site as determined by the $\frac{3}{4}$ inch loop was 73%. Siberian sandwort, alpine sagebrush (Artemisia scopulorum A. Gray), stonecrop (Sedum spp.), and tufted phlox (Phlox caespitosa Nutt.) were also locally prominent in the plant cover on other sites.

Alpine turf areas where the sod was thinner were characterized by most of the same species only in lesser amounts. However, the grass

A

B

C

Figure 4. Alpine turf sites on level to moderate slopes which are representative of plant cover classes: A, above 60%; B, 40 to 60%; C, below 40%.

and grasslike plants were in the minority on most of the sites. Cushion-forming forbs were more prominent in the plant cover and the sod-forming species persisted only as isolated plants. Such conditions were found on exposed ridges and in saddles or passes where the full effect of the wind was concentrated. They were also found on somewhat less extreme sites which had been used for years as sheep bedgrounds.

Total herbage production on alpine turf sites averaged 363 pounds per acre, air dry. Kobresia and sedges produced 39% of the total herbage and golden avens produced 20%. Bluegrasses and clovers were the only other plants that contributed more than 5% to the total herbage production. The production of grass and grasslike and forb species averaged 595 pounds per acre, air dry, on those sites where the plant cover exceeded 60%. Production of grass and grasslike plants was approximately 60% of the total production on these sites. In contrast, on sites with 40 to 60% plant cover, production averaged 276 pounds per acre, air dry, of which 38% was grass and grasslike plants and 62% was forbs. Production in one windswept site averaged only 65 pounds per acre, air dry.

Sheep grazing was encountered on only four turf sites during the two-year survey. Utilization in per cent of herbage weight removed on the four sites averaged only 7.0%, ranging from 2% at one site to 16% at another. Grasses and grasslike plants averaged 8.0% utilization; and forbs, 5.1%. Twenty-two of a total of 40 plant species found on these sites were grazed to some degree but, on the average, only 14 were utilized 5% or more (Table 2). The average utilization ranged from 30% of the herbage weight of agoseris (Agoseris spp.) to less than 5% for 8 of the species. These included spike trisetum, alpine fescue (Festuca ovina var. brachyphylla (Schult.) Piper), clovers, golden avens, fleabane (Erigeron spp.), saxifrage (Saxifraga spp.), tonestus (Tonestus pygmaeus (T. and G.) A. Nels.), and gentian (Gentiana spp.). The average utilization of kobresia, Carex elynoides and their mixture was 18% on 3 sites. This, coupled with their comparatively high herbage production, appears to make them the most valuable forage plants on the turf sites.

Kobresia was grazed less than 2% on one site studied in early August, and on 2 other sites studied in mid-September, use averaged 26%. Golden avens showed no use in early August but did show measurable use on sites examined in September. Other species showed no consistent pattern of seasonal utilization.

Alpine Meadow Sites

Alpine meadows were encountered on sites from within the forest fringe to the mountain tops and included within their matrix the wet bogs and stands of upright willows. Some meadows were extensive in area whereas others were small, relatively isolated pockets within the alpine turf. Frequently, alpine meadows were found on terraces formed behind rocky outcrops (Figure 5) or below snowfields.

Most meadows were on comparatively level topography, although slopes in excess of 60% with meadow vegetation were studied. On most slopes in excess of 30% there was a noticeably poorer vegetative cover. Sometimes this was associated with a late-lying snowfield that did not melt in time to permit a vigorous meadow vegetation.

Table 2. Herbage production and utilization by sheep of forage species on grazed alpine turf sites of the central Rocky Mountains.

Plant	Average utilization %	Average herbage production lbs/acre, air dry	Forage grazed lbs/acre, air dry
Agoseris	30	9	3
Alpine oreoxis	23	22	5
Graylocks actinea (*Hymenoxys grandiflora* (T. and G.) Parker)	20	16	3
Aster (*Aster* spp.)	20	14	3
Wild yellow parsley (*Pseudocymopterus montanus* (A. Gray) Coult. and Rose)	20	36	7
Common alplily (*Lloydia serotina* (L.) Sweet)	18	8	1
Dwarf clover	18	50	9
Kobresia	18	186	33
Goldenrod (*Solidago* spp.)	10	30	3
Fendler sandwort (*Arenaria fendleri* A. Gray)	8	5	0.4
Painted-cup (*Castilleja* spp.)	8	4	0.3
Sedge	7	60	4.0
Skypilot polemonium (*Polemonium viscosum* Nutt.)	5	6	0.3
Bluegrass	5	40	2
Others	1.2	18	2

Figure 5. Meadow vegetation was often found on terraces behind rocky outcrops or in locally sheltered areas within the alpine turf.

Table 3. Characteristic plants of alpine meadow sites ranked according to the product of their frequency and abundance.

Plant	Index of frequency X abundance	Frequency of Occurrence (%)	Average abundance per site[1] (%)
Tufted hairgrass	834	81	10.3
Sedge	806	96	8.4
Clover	428	68	6.3
Fleabane	303	74	4.1
Bluegrass	256	80	3.2
Sibbaldia	201	59	3.4
Golden avens	189	46	4.1
Alpine sagebrush	123	56	2.2
Whortleberry	102	33	3.1
Pussytoes	101	46	2.2

[1] Number of encounters per 100 loop observations.

A total of 54 sites on 27 areas within 10 national forests was studied. Sites varied from very moist to an indistinct transition zone between meadow and turf.

Like the alpine turf sites, the bulk of the plant cover on the meadows consisted of relatively few species. The most prominent plants recorded by the loop method on alpine meadow sites are ranked according to their indices of frequency times abundance in Table 3. Ten plants had indices above 100. Four of these on the meadow sites were also listed in the alpine turf. Indices on both sites were similar for sedges, clovers, and bluegrasses. Golden avens had an index more than twice as great on the turf sites: 413 vs. 189. This species was tallied on 78% of the turf sites but on only 46% of the meadow sites.

Tufted hairgrass (Deschampsia caespitosa (L.) Beauv.) replaced kobresia as the most abundant and constant plant of the meadow sites. However, on sites where water was ponded for most of the growing season, tufted hairgrass was replaced by one to several moisture-loving sedges, which included Carex albo-nigra Mack, C. aquatilis Wahl. C. bella L.H. Bailey, C. illota L.H. Bailey, and C. physocarpa Presl. Several species of fleabane were fourth highest on the meadows in contrast to an index of 76 on the turf sites. Sibbaldia (Sibbaldia procumbens L.), whortleberry and pussytoes (Antennaria spp.) were also more prominent on alpine meadow than on turf sites.

Plant cover on 8 meadow sites was over 60% and on 36 sites was between 40 and 60%. The plant cover on the other sites was less than 40%. The maximum plant cover on the meadow sites was 74% and the minimum was 28%. On the site with the highest plant cover, bare ground was recorded within the $\frac{3}{4}$-inch loop only once but on the site with least plant cover bare ground was recorded on 60 observations. The plants with the

highest frequency-abundance indices constituted over 60% of the plant composition on sites having a plant cover of less than 40% as well as those with a plant cover of more than 60%.

Thurber fescue (Festuca thurberi Vasey) was present on some drier and usually sheltered sites within the transition from forest to alpine in southern Colorado and northern New Mexico. It also occupied old burns of the forest fringe transition. Tufted hairgrass was not found on these sites although several bluegrasses, sedges, and other plants commonly found on most alpine meadows were. A site in northern Wyoming that was once a spruce forest was dominated by sedges instead of Thurber fescue although such secondary species as bluegrasses, Siberian sandwort, pussytoes, cinquefoil (Potentilla spp.) and fleabane were common on both areas.

Herbage production on the alpine meadows ranged from 1,108 pounds per acre, air dry, to 132 pounds per acre, air dry, and averaged 626 pounds on 28 sites. Grass and grasslike plants contributed about 60% of the total production. The highest production was on a very wet site and large, moisture-loving sedges contributed the bulk of the herbage production. On somewhat drier meadow sites, tufted hairgrass produced the most herbage. Herbage production of this species declined on sites where plant cover was low and vigor was reduced as evidenced by shorter leaves and seed stalks and smaller plants.

As shown in the following tabulation, of the 5 plants having the highest frequency-abundance indices, tufted hairgrass, on the average, produced 20% of the total herbage:

	Herbage Production Pounds per acre, air dry		
	(Average)	(Range)	(%)
Tufted hairgrass	124	14-478	20
Sedge	78	7-770	12
Golden avens	42	6-358	7
Bluegrass	17	2-149	3
Alpine sagebrush	16	5- 88	3

No other individual plants averaged more than 15 pounds of air-dry herbage per acre.

On the meadow and turf sites, utilization of the alpine vegetation was seldom uniform or very intensive. Sheep on most alpine areas were usually widely spread while grazing (Figure 6).

Sheep had grazed 20 of the alpine meadows observed. Utilization of herbage averaged only 7%. Grasses and grasslike plants were utilized slightly more than forbs but a rather wide variation in species utilization was measured among the sites. On three sites, utilization of grass and grasslike plants averaged above 20%; the highest utilization was 35%. Heaviest utilization was on tufted hairgrass, sedge and bluegrass. On these same sites, forb utilization varied from less than 1% to more than 18%. Where utilization was 18% on forbs, onion (Allium spp.), elkslip marshmarigold (Caltha leptosepala DC.), and dandelion (Taraxacum spp.) were most heavily grazed. On a site dominated by Thurber fescue, sheep fescue (F. ovina L.), smooth brome (Bromus inermis Leyss.), and

Figure 6. When grazing, sheep are usually widely spread over the alpine ranges.

Scribner wheatgrass (Agropyron scribneri Vasey), utilization of grass and grasslike species averaged less than 1%, whereas forb utilization was 32%. Heaviest use occurred on Porter ligusticum (Ligusticum porteri Coult. and Rose).

Of the 65 plants found on the grazed meadow sites, 10 grass and grasslike plants, 32 forbs, and 2 shrubs had been utilized to some extent. Utilization of herbage averaged 5% or higher on only 24 plants of the meadow sites (Table 4). Some species frequently were grazed consistently. For example, tufted hairgrass and sedges were utilized on over 70% of the sites where sheep had grazed. These plants were utilized an average of 9% and produced more sheep forage than other species. Bluegrasses were utilized 7%; however, herbage production of bluegrasses on the meadows was much lower than tufted hairgrass and sedge. Spike trisetum, alpine fescue, and rush (Juncus spp.) were relatively consistent species on the meadow sites, each having frequency values above 35%, but none were individually important insofar as herbage production or degree and frequency with which they were utilized.

Kobresia was found on three sites that were transitional between meadow and turf. Utilization of kobresia averaged highest of all grass or grasslike plants on the meadow sites.

Table 4. Herbage production and utilization of forage species on alpine meadow sites of the central Rocky Mountains.

Plant	Average utilization (%)	Ave. Herbage Production lbs/acre, air dry	Forage grazed lbs/acre, air dry
Onion	40	8	3
Kobresia	23	21	4
Agoseris	19	7	1
Common alplily	17	5	1
Porter ligusticum	15	18	2
Beardtongue (Penstemon spp.)	15	5	T[1]
Buttercup (Ranunculus spp.)	14	16	2
Pedicularis (Pedicularis spp.)	14	6	1
Milkvetch (Astragalus spp.)	13	3	T[1]
Dandelion	12	10	1
Alpine oreoxis	11	19	2
Sedge	10	103	9
Tufted hairgrass	10	165	15
Willow	9	-	-
Elkslip marshmarigold	7	23	1
Fleabane	7	17	1
Groundsel	7	26	2
Bluegrass	7	24	2
Scribner wheatgrass	6	13	1
Gentian	6	8	T[1]
Aster	5	8	T[1]
Harebell (Campanula spp.)	5	2	T[1]
Rush	5	25	1
Clover	5	9	T[1]

[1] Trace

Certain forbs are preferred by sheep and, because of their relatively consistent presence and utilization, are valuable forage species on the meadow sites. Aster, elkslip marshmarigold, fleabane, and groundsel (*Senecio* spp.) were found on at least 59% of the meadow sites where utilization was observed; each was utilized an average of at least 5%; and each produced a measurable amount of herbage. Agoseris was utilized an average of 19% and produced an average of 7 pounds of air-dry herbage per acre but it was not present on most sites. Other forbs were often present but were infrequently grazed.

In general, sedge, tufted hairgrass, alpine timothy (*Phleum alpinum* L.), fleabane, gentian, and groundsel were grazed throughout the period from mid-July to early September. On other plants, grazing was observed to be limited to particular periods. For example, bluegrass and elkslip marshmarigold were not found grazed after mid-August, but rush and alpine sagebrush were utilized only after late July. Golden avens was not grazed until mid-August, after which measurable utilization was recorded on four sites. Other meadow plants exhibited no discernible pattern of utilization on the limited sample.

Seldom were sheep observed grazing areas with standing water, even though such areas furnished abundant herbage. The drier perimeters around the bogs furnished most of the grazing.

Willow fields contribute an undetermined amount to the over-all forage resources of the alpine type. Sheep grazing is restricted to the periphery of dense stands, but where the stands are more open, either because of site differences or through grazing, extensive use is made of certain species of these shrubs (Figure 7).

SUMMARY

An extensive survey of alpine range areas in Colorado, Wyoming, and New Mexico was made during the summers of 1955 and 1956 to determine the more gross characteristics of the vegetation and its use by domestic sheep.

The alpine region is diverse in physiography, soils, and climate. The plant cover exhibits a number of abrupt and distinctive differences that complicate understanding and management of the forage resources. The severe environment is characterized by strong winds, low temperatures, unstable soils and steep slopes.

Alpine vegetation was categorically grouped as turf or meadows. Turf sites were found on better drained, more exposed areas than were the meadows. Vegetation was studied on 100-pace transects by use of $\frac{3}{4}$ inch loop placed at the point of the shoe to obtain an index of plant density and within a 9.6 sq. ft. circular frame to estimate herbage production and utilization.

Based upon an index computed from the product of the frequency and abundance of each species, the most common turf plants were determined to be kobresia and the closely similar *Carex elynoides*. Meadow vegetation was characterized by tufted hairgrass. On both sites other sedges were second in importance, followed by clovers. In general, the same species were dominant on alpine sites having dense cover as those having sparse cover.

Figure 7. Heavy grazing on willows has opened the stand and lowered the vigor of the shrubs.

Herbage production on the alpine turf sites averaged 363 pounds per acre, air dry, and on the meadow sites it averaged 626 pounds. Production was greatest on meadow and turf sites, which had the greatest plant density.

Sheep grazing was usually light on the alpine vegetation. During the 2-year survey, average utilization as expressed in per cent of herbage weight removed was only 7%. Certain species were grazed more heavily than others; however, because they were less prominent in the plant cover, they contributed relatively little to the forage requirements of the sheep. Kobresia and Carex elynoides on the turf sites and tufted hairgrass and sedge on the meadow sites furnished most sheep forage on alpine ranges.

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AN ABRIDGED HISTORY OF SOUTHERN RANGE RESEARCH[1]

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INTRODUCTION

Grazing has developed into an important part of the South's agricultural economy over the years since 1521, when Ponce de Leon brought the first cattle to the United States and put them ashore on the southwest coast of Florida. Fine improved pasturelands developed in recent years provide much cattle forage; in addition, the native woodlands and other range lands of the southern Coastal Plain provide grazing for several million head of beef cattle.

The importance of the native range long has been recognized, but it has been only within the past 30 to 40 years that native range problems have been studied and research undertaken toward their solution. This paper develops a history of that research.

RANGE RESEARCH PIONEERS

Not too far from where Hernando de Soto traveled past Payne's Prairie near Gainesville, Florida, Camp (1932) studied range cattle management in 1931. He found that ranges were burned frequently to provide nutritious forage and to reduce ticks; calf crops were small with low gross returns per cow; cows became "salt-sick" from lack of minerals such as iron and copper; quality of cattle, although somewhat improved above the original Spanish breeds, was poor, with mixtures of Brahman, Devon, Jersey, Ayrshire, and other breeds. He found that these cattle gained well on wiregrass pastures during the spring and early summer but declined in condition during the rest of the year because of the low forage value of the mature grass.

Workers at McNeill in southern Mississippi had found similar conditions when they began grazing work in 1923. This work led to the classic Wahlenberg, Green, and Reed publication (1939) on effects of fire and grazing on longleaf pine lands.

Studies in beef cattle production got under way in 1928 in the canebreaks of North Carolina (Foster et al. 1937).

All of the early work was valuable in setting the stage for later work on range management problems. It was useful to Biswell, Campbell, Cassady, Southwell, Shepherd, and others who began intensive study

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toward better management of our large forest land grazing resource. It provided problem bases from which most of the southern range management research has proceeded.

CENTERS OF RESEARCH

From a 1941 survey in the Coastal Plain of Georgia was developed an analysis (Biswell and Southwell 1942) of the problems used to guide a new cooperative range research program between the Forest Service and the old Bureaus of Animal Industry and Plant Industry (Agricultural Research Service) of the U.S. Department of Agriculture, the Georgia Experiment Station, and the Georgia Coastal Plain Experiment Station (Biswell et al. 1942). A similar survey approach was used in North Carolina in 1940-1941 to explore forest grazing and beef cattle production problems (Biswell and Foster 1942). Cooperating with the same U.S. Department of Agriculture agencies in the North Carolina work which followed the survey was the North Carolina Agricultural Experiment Station.

The Alapaha Experimental Range, owned by the Georgia Agricultural Experiment Station, became the center of the Georgia range work. In North Carolina, the work centered at the old Blackland Station and Hofmann Forest until the late 40's, and then at the Tidewater Research Station and the Frying Pan Experimental Range until field activities were terminated in 1954.

By the time the Alexandria Research Center—a field unit of the Southern Forest and Range Experiment Station—was established in 1946, grazing work in Louisiana already was under way. Dr. R. S. Campbell in 1943 had started studies in forest grazing, forest range improvement, and the use of chemicals to control scrub oaks (Cassady and Mann 1954). In 1946, studies on woodland herbage production were begun in the Arkansas Ozarks by the Southern Forest and Range Experiment Station in cooperation with the Arkansas Bureau of Research (Read 1951). Other work on grazing problems began in Missouri in 1948 (Chapline 1949).

Forest Range studies beginning in southeast Texas in 1947 led to the development of better ways for utilizing the large forest range area by planting and grazing of seeded firebreaks, control of undesirable hardwoods, and other management methods (Silker 1955b, Silker et al. 1950). These and other studies were prompted by much evidence of poor forest range management (Silker 1955a).

Intensive range research did not begin in the south Florida range area until late 1953. An analysis of range problems in south Florida was published in 1956 (Rummell 1956). The report showed that in this area, with more than 10 million acres of native range and a population of over 1 million head of beef cattle, a very low level of native range and cattle management was practiced. In 1955, the Caloosa Experimental Range, an area owned by a large cattle company, became the center for U.S. Department of Agriculture range research in south Florida under the Lake City Center of the Southeastern Forest and Range Experiment Station, Forest Service.

RESEARCH PROGRESS

Range research developed in all areas in somewhat similar patterns. After the basic problems were established, work was started leading to better understanding of the range environment and how to manage it for maximum livestock production. More recently, work has explored relationships between use of the range for grazing and for other land management objectives.

A 1955 publication based on work by the Southern Section of the American Society of Range Management has proven useful in highlighting the importance of nine broad southern forest range types and their special problems (Williams et al. 1955).

Forage Plants

One of the first range research undertakings in the South in each research area was study of the forage plants. This was a necessary and logical step toward later studies in all phases of native range grazing research.

The principal native forage plants on forest range in the North Caroline Coastal Plain and their nutritional values were outlined in 1945 (Biswell et al. 1945). Similar work was carried out in south Georgia (Biswell et al. 1943).

Grazing values of plants on pine forest range in Louisiana were studied from 1944 to 1949 (Campbell and Cassady 1951). Described were the seasonal qualities and limitations of the forest range and how it could be used profitably. Other Louisiana work drew together valuable information on the forage and other values of important plants on the bluestem ranges of the west gulf longleaf pine region (Langdon et al. 1952). South Florida work in 1954 resulted in the collection and identification of over 350 forage plant species (Rummell 1954).

As range research continued, information on poisonous plants accumulated. This information was published for North Carolina in 1943 (Shaw et al. 1943), and for Florida in 1950 (West and Emmel 1950). Both publications pointed to the possibility of serious cattle losses from poisonous plants.

Basic to all range research in the South has been the finding that forage from the native range does not meet animal nutritional requirements year-round. This knowledge has resulted in the development of mineral supplements containing elements in which the forage is deficient. The disease "salt-sick" was recognized as being caused by lack of iron, or copper and iron in forages grown on some Florida soils (Becker et al. 1931). An iron-copper-salt lick was recommended as a corrective for the "salt-sick" condition.

Research in the Atlantic Coastal Plain of the Carolinas, Georgia, Louisiana, Texas, and elsewhere in the South has pointed out the nutritive contents of wiregrass and other range vegetation and mineral needs of cattle throughout the year (Beeson 1955; Campbell et al. 1954; Duncan and Epps 1958; Fraps and Fudge 1940; Halls et al. 1957b; Hilmon 1957; Lazar and Beeson 1956). Studies beginning in Florida in 1932 pointed to seasonal variation in the amount and quality of forage on native ranges

as an important factor responsible for weight changes of range cattle throughout the year (Kirk et al. 1945).

Range Seeding

Efforts to improve forage quality led to studies in range seeding. This work was given encouragement through Congressional assistance in 1945, when certain funds were made available for range seeding research.

Beginning in 1946, species, seeding methods, and fertilizing practices were studied in the lower Coastal Plain of Georgia. By 1949 the Georgia work had shown that several grasses and legumes could successfully be introduced into the range (Burton and Mathews 1949).

As a means for low-cost range improvement, burning of wiregrass in June, July, or August was suggested as a satisfactory site preparation for top seeding of carpetgrass or bahia (Killinger 1948). Summer burning apparently reduced the vigor of the wiregrass and lessened competition from it to the seeded grasses.

Range seeding research carried on at the Alapaha Experimental Range from 1949 to 1954 showed that successful stands of Dallis grass could be established where native vegetation was destroyed and mineral soil exposed. In these studies, carpetgrass became the most abundant and important grass for grazing on all ranges, regardless of land preparation or seeding treatment (Halls et al. 1957a).

Louisiana studies, started in 1945, led to several successful ways for improving forage conditions by planting grasses and legumes on forest range (Cassady and Mann 1954).

Supplemental Feeding

The practicability of feeding wintering beef cows on forest range in the Coastal Plain of North Carolina was brought out by studies beginning in 1941 (Foster et al. 1945). Earlier, cottonseed cake was reported as a useful supplemental feed for wintering cattle on pasture in Florida (Henley 1937).

Alapaha Experimental Range studies showed that starvation losses could be avoided and the productivity of range herds increased at reasonable cost by supplementing the range diet with concentrated protein feed during the fall and early winter, and by withholding the cattle from freshly burned range until forage had developed adequately in the spring (Shepherd et al. 1953).

Additional feeding studies were undertaken to explore the gains to be made from winter feeding at higher nutritional levels than those used in earlier tests. In Georgia, an immediate response to a high level of winter feeding was observed. Calf crop and weaned weight of calves were higher (Halls and Southwell 1956). Calf crops of better than 75%, and weaning weights of over 400 pounds resulted.

Louisiana studies followed much the same pattern as those in Georgia. Initial trials in 1946, in which cattle were fed cottonseed meal for about 90 days in the winter, did not result in materially increased beef production at the Alexandria Research Center (Campbell et al. 1954). The

results suggested that long-season supplementation was needed for sustained high-beef production. Studies of the nutritive deficiencies of native forages also led to the conclusion that cottonseed meal alone was not an adequate supplement. Easily digested energy foods, vitamins, and selected minerals were also needed in the supplemental ration.

In later Louisiana trials, cattle fed a mixed feed ration containing 11 to 15% protein from mid-July to May weaned calves weighing 409 pounds with a 77% calf crop; cows fed 41% protein cottonseed cake from November to May weaned calves at 453 pounds with an 85% calf crop (Southern Forest Experiment Station 1957).

These returns are a far cry from the 200-250 pound calves and less than 50% calf crops so common in the South in the early 1940's and still not unusual where the old-type range management is practiced.

Grazing Capacity

For many of the 400-odd years that cattle have grazed southern forest ranges, cattle have been stocked on an experience basis without benefit of accurate knowledge as to what constitutes proper stocking. Stocking rates vary widely. Some wiregrass range is stocked at 8 to 10 acres per cow per year, while other wiregrass range is stocked at 20 to 30 acres per cow per year.

Perhaps, as many a rancher has said, he didn't need someone to tell him how many cows to stock per section of rangeland. If there were too many cows, the extra ones died off until the range was properly stocked. But there were those who did not believe in quite such severe ways for regulating cattle numbers. Studies were undertaken to gain evidence leading to proper stocking rates. Grazing-capacity studies have been made in the wiregrass-pine ranges of Georgia (Halls et al. 1956). Rates studies are in progress in the cutover pine forest rangelands of south Florida. Estimates of grazing capacity have been made for other southern range areas.

Plant Control

Intensified management of forest rangelands in the South has focused attention on the need for controlling or getting rid of some of the more common undesirable forage plants. Undesirables frequently take the space and moisture which might be used by forage producers. Saw-palmetto, gallberry, and various weedy hardwood species, in one place or the other, are classed as undesirables.

Effects of various chemicals on gallberry have been studied (Halls and Burton 1951). Other unreported studies are under way on gallberry and saw-palmetto. Basic autecological research is being started on saw-palmetto which should assist in directing needed phytocidal and other control work on this undesirable forage plant.

Grazing and Other Forest Land Uses

Early in the history of grazing research in the South, the forests of the Coastal Plain were shown to offer the greatest possibilities of the

timbered range areas for successful integration of cattle raising and timber production (Shepherd 1952). Research at the Coweeta Hydrologic Laboratory showed that grazing of mountain hardwood forests damaged soils and young trees and has little to recommend it (Johnson 1952).

In 1940, Nieland (1945) recognized the possibilities of raising timber, cattle, and game together under an integrated type of management. He proposed that improved pasture fire barriers be established around and through forest areas. Grazed firebreaks subsequently have been proven practical in several southern areas. Near Cordele, Georgia, seeded and grazed firebreaks made an effective fire barrier during the grazing season when grasses were green and closely grazed (Hughes 1957). When winter annuals were planted each fall, the effectiveness of the firebreaks was extended into the fall and winter months.

Florida studies reported in 1954 (Jones et al. 1954) showed how the acreage required per cow could be reduced and more forage of higher quality made available by using native and improved pastures to supplement each other.

A sound plan for combining timber and cattle raising on southwest Louisiana's cut-over pine land was presented in 1951 (Bond and Campbell 1951). This plan, based upon research results obtained by several cooperating Louisiana agencies, outlined recommended ways for burning the range and grazing cattle in pine plantations to minimize cattle damage to trees. It suggested the use of seeded firebreaks and improved permanent pastures along with the native range to provide an adequate year-round forage supply. Supplemental feeding was recommended.

Other studies have shown that grass yields drop as timber stand density increases (Halls et al. 1952, 1956; Smith et al. 1955) and that weight of tree litter affects herbage production (Gaines et al. 1954; Wahlenberg et al. 1939).

More recently, studies have been undertaken to explore the possibilities of raising trees and cattle under true "integration." On the Alapaha Experimental Range, trees have been planted at various spacings on carefully prepared land and kept clean-cultivated. When the trees have reached heights where cattle damage is not expected to be significant, improved pasture grasses will be planted between the tree rows. After the grasses are established, the grassed plantations will be grazed by cattle. Beef cattle production under this type of management and the effects of cattle grazing on tree growth will be determined.

Effects of three intensities of grazing on survival and growth of planted longleaf, common, and south Florida slash pines are being studied on the Caloosa Experimental Range.

The present trend toward site preparation before planting trees presents challenges for investigating how cattle and trees can be managed together for maximum economic returns.

Range Burning

Most southern grazing management studies have employed fire in some manner to improve forage quality. From the cane forage type of North Carolina to the pine-wiregrass flatwoods of south Florida and west to Louisiana, range men have burned the "rough." Cow gains on freshly

burned wiregrass frequently have been a pound per head per day. However, as the wiregrass matured and its nutritive value dropped, cows lost weight unless the range was supplemented.

Range burning, long present in the history of southern range use, has been to some an evil thing. If carelessly handled, destruction of forest trees has resulted. Growth of surviving trees has been slowed by fires (Mann 1947).

Some of the silvicultural benefits of controlled fires have been studied. Burning has been found to reduce accumulation of herbaceous fuel, and thus reduce the risk to trees from accidental fires (Bickford and Curry 1943; Biswell et al. 1943; Halls et al. 1952). Yet, with the continued use of fires for betterment of range forage quality, there remain many unanswered questions.

What are the proper climatic conditions and when, and how, should one burn to obtain a fire that results in minimum damage to trees, wildlife, and soil, and yet provides a maximum amount of nutritious forage? How can one extend the green forage period through burning? What are the effects of burning on quail, turkey, and other wildlife? What is the optimum size burn conducive to good quail management? Does this size burn meet the needs for cattle production? Is burning necessary on all forage types when cattle are supplemented? These are only some of the unresolved questions related to use of fire on the ranges of the South.

Wildlife Habitat Research

Although most forest range work in the South has been directed toward cattle and other livestock management problems, some excellent work has directly or indirectly benefited wildlife inhabitants of the forest range. And, with the broadening recognition of the tremendous resource values of wildlife populations, studies are being directed specifically toward improvement of forest wildlife habitat.

The Forest Game Research Committee, formed by the Southern Section of the Wildlife Society and agencies concerned with wildlife research, has stimulated and is coordinating work in several phases of wildlife habitat research. Useful in suggesting needed wildlife habitat research is an analysis of problems by Burke (1956).

New studies on wildlife habitat management by the Southern Forest Experiment Station and its cooperators, and proposed studies in this field by the Southeastern Forest Experiment Station, and the various private, State, and Federal wildlife research agencies should soon provide some of the needed answers in this most important field of forest research.

Methods and Techniques

Most range research work in the South has been somewhat slowed because of the inadequacy of existing methods and techniques for sampling range vegetation. Long growing seasons, regrowth of grazed vegetation during a given grazing season, and even such factors as perennating growth of some grass stems and leaves have presented special measurement problems. Range scientists have been resourceful in

devising appropriate sampling methods, techniques, and statistical procedures.

CONCLUSION

The 30 to 40 years of southern range research have contributed much toward solution of ranchers' problems. Native range grazing is coming of age. No longer is it considered good range management to turn cows out on native range with uncontrolled breeding seasons, lack of proper minerals and salt, and no insect or parasite control. Native range management now aims at a year-round program of good cattle management and forage-and-feed intake adequate for the animal's nutritional needs. But more remains to be accomplished.

Not all range calves wean off at 450 to 500 pounds; planted trees still suffer damage from cattle. Range burning for betterment of forage quality frequently harms trees. Methods for integration of cattle, deer, quail, turkey, and other wildlife with timber production on a majority of southern range areas are not available. Only through continued study toward solution of these and related range problems can methods be developed for making full and effective use of the South's large rangeland resource.

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